

Abstract

WISEMAN, JACOB DAVID. Groundwater Nitrate Reductions in a Managed Riparian Buffer Located in the Upper Coastal Plain of North Carolina. (Under the direction of Michael R. Burchell II).

Riparian buffers have been of interest as a significant best management practice to land planners attempting to decrease the effects of non-point pollution in watersheds for many years. However, not all of the processes involved in pollutant reductions in riparian buffers are fully understood. This is especially true of nitrate-nitrogen ($\text{NO}_3\text{-N}$) removal in groundwater moving through riparian buffers. A better understanding of the processes may lead to a better allocation of resources in buffer establishment and larger improvements in basin-wide water quality.

With this in mind, a 5 year old riparian buffer in the upper coastal plain of North Carolina was studied for 6 years to determine the buffer effectiveness in meeting the water quality goals of the basin it was located in, the Tar-Pamlico River Basin.

Three monitoring blocks were established along a first-order stream in a 46 m (150 ft) riparian buffer. The monitoring blocks were positioned at different elevations within the buffer, Block 1 located the furthest downstream and lowest in elevation while Block 3 was located the furthest upstream and highest in elevation in the buffer. Block 2 was positioned between Block 1 and Block 3. Groundwater concentrations of $\text{NO}_3\text{-N}$, chloride (Cl^-), dissolved organic carbon (DOC) and soil redox potentials were all assessed on a monthly interval at various locations in each monitoring block.

Analysis showed that $\text{NO}_3\text{-N}$ concentrations decreased significantly across the buffer in all of the monitoring blocks with mean percent reductions of 92%, 76%, and 77% calculated for Block 1, Block 2, and Block 3 respectively. Mean soil redox potentials indicated that the reducing conditions needed for denitrification to occur in the buffer soils were present for a majority of the monitoring period in all monitoring blocks. Dissolved organic carbon (DOC) concentrations in groundwater were likely marginal to support high rates of denitrification during a majority of the sampling period. However, large spikes of DOC were sometimes sampled throughout the buffer which would have greatly increased the potential for denitrification to occur in the groundwater. Block 1 had the highest mean DOC concentration of 5.7 mg/L, while Block 2 and Block 3 had mean DOC concentrations of 4.5 mg/L and 4.1 mg/L respectively. Low DOC concentrations were thought to be the most limiting factor in $\text{NO}_3\text{-N}$ removal due to denitrification.

Chloride (Cl^-) concentrations, used as an indicator of the dilution of $\text{NO}_3\text{-N}$ concentrations in the analysis, were also found to have significant decreases in concentration across all of the buffer monitoring blocks. Mean reductions in Cl^- concentrations of 63%, 65%, and 48% were calculated for Block 1, Block 2, and Block 3 respectively. This indicated that dilution was a major factor in $\text{NO}_3\text{-N}$ concentration reduction in all of the monitoring blocks.

In order to estimate the maximum amount of $\text{NO}_3\text{-N}$ reductions that could be attributed to denitrification the percent reduction in Cl^- concentrations across the buffer was subtracted from the percent reduction in $\text{NO}_3\text{-N}$ reductions across the buffer. Maximum

percent reductions in $\text{NO}_3\text{-N}$ that could be attributed to denitrification were 40%, 17%, and 32% for Block 1, Block 2, and Block 3 respectively. These values were much lower than what many previous studies have attributed to denitrification.

Block 1 was thought to outperform the other blocks in biological $\text{NO}_3\text{-N}$ removal due to its higher water table, which may have allowed more available DOC to leach into the groundwater, increasing the potential for denitrification to occur. This seemed to suggest that riparian buffers with high water tables and poorly drained soils may have a higher potential for denitrification to occur. The analysis further emphasizes the importance of accounting for groundwater mixing and dilution in riparian buffer studies as failing to do so may cause a large overestimation of biological removal of $\text{NO}_3\text{-N}$ in the buffer.

Groundwater Nitrate Reductions in a Managed Riparian Buffer Located in the Upper Coastal
Plain of North Carolina

by
Jacob David Wiseman

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of
the requirements for the Degree of
Master of Science

Biological and Agricultural Engineering

Raleigh, North Carolina

2011

APPROVED BY:

Dr. Garry L. Grabow

Dr. Deanna L. Osmond

Dr. Michael R. Burchell II
Chair of Advisory Committee

Dedication

To my Parentals,

*Mom and Dad, your continued support has formed the backbone to all my current success
and will do the same in the future*

To my Colleagues,

Tiffany and Amey, your continued support was critical to this projects completion

Biography

Jacob David Wiseman was born in Charlotte, NC to David and Christy Wiseman on February 13, 1986. He was raised in Mooresville, NC, just north of Charlotte, near Lake Norman. He was lucky enough to have parents that provided the opportunities and helped to form a love of the outdoors in Jacob. His parents emphasized the importance of stewardship in local resources.

This background, along with the rapid growth of the Lake Norman region were two of the major reasons that Jacob chose to enroll in the Biological and Agricultural Engineering program at North Carolina State University. After his senior design project, under Dr. Mike Burchell, he chose to also enroll in the graduate program at North Carolina State University to further his understanding of ecological engineering principles.

He hopes that these experiences will lead to life-long work in improving water quality and engineering in the future.

Acknowledgements

First I would like to thank my adviser, Dr. Michael Burchell, his insights and suggestions improved this project many times over compared to what I would have produced alone.

I would also like to thank my committee, Dr. Osmond and Dr. Grabow whose help and expertise has been vital to the completion of this project.

My colleagues, Amey Tilak and Tiffany Messer, who were always there for a quick discussion, extra insights, as well as the hard work that was crucial to the completion of this project. The mutual support we have shared has been formative for me in how I will model my future relationships with colleagues

All of those who have helped on the NC CREP research crew deserve a special mention: Jamie Blackwell, Mike Shaffer, Cory George, Spencer Davis, Laura Lord, Bill Price, Randall Etheridge and Chris Muhs. Their efforts to collect the needed information, no matter the conditions was central to making this project possible. Time spent with the research crew will likely form the most lasting memories from this project.

Finally, the BAE laboratory staff that analysed countless samples from the CREP sites. Rachel Huie, Hiroshi Tajiri, and Ryan Libert were indispensable for the vital work they performed in ensuring that the CREP team always had the accurate, timely results that were needed for our analysis. **THANK YOU ALL!!!**

Table of Contents

List of Tables	xii
List of Figures	xiv
CHAPTER 1: GENERAL INTRODUCTION	1
Introduction	1
Historical Background	1
Riparian Buffers	2
Reduction of NO_3^- Through Denitrification	4
Impacts of Dilution on Measured $\text{NO}_3\text{-N}$ Concentrations in Riparian Buffers.....	8
Vegetation Uptake	8
Estimating Buffer Effectiveness	9
Objectives.....	13
References	15
CHAPTER 2: FATE OF NITRATE AND HYDROLOGY OF MONITORING BLOCK 1 21	
Introduction	21
Measuring Denitrification.....	21
Measuring Dilution.....	25
Materials and Methods	26
Site Description	26
Soils Description.....	31
Groundwater Monitoring.....	33
Groundwater Quality Sampling.....	38
Water Table Measurements	40
Soil Sampling	41
Rainfall Measurements	42
Redox Potential Probes.....	43
Site Survey.....	43
Flux and load Calculations	44

Residence Time Calculations	48
Statistical Methods	49
Results	50
Particle Size and Hydraulic Conductivity	50
Rainfall	51
Groundwater Hydrology.....	52
Water Table Proximity to the Ground Surface.....	53
Flow Direction.....	55
Residence Time	56
Groundwater Quality – Nitrate (NO ₃ ⁻)	57
Redox.....	65
Groundwater Quality – Dissolved Organic Carbon (DOC)	74
Groundwater Quality – Nitrate/Chloride Ratios (NO ₃ -N/Cl ⁻).....	77
Groundwater Quality – Chloride (Cl ⁻).....	82
Groundwater Quality – Cations.....	93
Discussion and Conclusion.....	98
References.....	102
CHAPTER 3: FATE OF NITRATE AND HYDROLOGY OF MONITORING BLOCK 2	
.....	107
Introduction	107
Materials and Methods.....	108
Site Description	108
Soils Description.....	108
Monitoring.....	109
Load and Residence Time Calculations	113
Results	113
Particle Size and Hydraulic Conductivity	113
Groundwater Hydrology.....	114

Water Table Proximity to Ground Surface.....	115
Groundwater Flow Direction.....	117
Residence Time	118
Groundwater Quality – Nitrate (NO ₃ ⁻)	119
Redox.....	127
Groundwater Quality – Dissolved Organic Carbon (DOC)	135
Groundwater Quality – Nitrate/Chloride Ratios.....	138
Groundwater Quality – Chloride (Cl ⁻).....	144
Groundwater Quality – Cations.....	156
Discussion and Conclusion.....	161
References.....	165
CHAPTER 4: FATE OF NITRATE AND HYDROLOGY OF MONITORING BLOCK 3	
.....	170
Introduction	170
Materials and Methods	171
Site Description	171
Soils Description.....	171
Monitoring.....	173
Load and Residence Time Calculations	176
Results	176
Particle Size and Hydraulic Conductivity	176
Hydrology.....	177
Water Table Proximity to the Ground Surface.....	178
Groundwater Flow Direction.....	180
Residence Time	181
Groundwater Quality – Nitrate (NO ₃ ⁻)	182
Redox.....	190
Groundwater Quality – Dissolved Organic Carbon (DOC)	198

Groundwater Quality – Nitrate/Chloride Ratios.....	201
Groundwater Quality – Chloride (Cl ⁻).....	207
Groundwater Quality – Cations.....	218
Discussion and Conclusion.....	223
References.....	227
Chapter 5: OVERALL BUFFER COMPARISON ACROSS ALL MONITORING BLOCKS	232
Introduction.....	232
Materials and Methods.....	233
Site Description.....	233
Statistical Methods.....	236
Results.....	236
Overall Summary of Results.....	236
Hydrology.....	238
Water Table Proximity to Ground Surface.....	239
Groundwater Quality – Nitrate (NO ₃ -N).....	241
Redox.....	245
Groundwater Quality – Dissolved Organic Carbon (DOC).....	246
Effect of Dilution – NO ₃ -N/Cl ⁻ Ratios.....	249
Discussion and Conclusion.....	256
References.....	261
APPENDIX.....	263
APPENDIX A: Chapter 2 Supplemental (Block 1).....	264
Block 1 Groundwater Hydrology.....	264
Block 1 Pasture Edge Redox.....	267
Block 1 Mid-Buffer Redox.....	270
Block 1 Stream Edge Redox.....	273
APPENDIX B: Chapter 3 Supplemental (Block 2).....	276

Block 2 Groundwater Hydrology	276
Block 2 Pasture Edge Redox	280
Block 2 Mid-buffer Redox	283
Block 2 Stream Edge Redox.....	286
Appendix C: Chapter 4 Supplemental (Block 3)	289
Block 3 Groundwater Hydrology	289
Block 3 Pasture Edge Redox	292
Block 3 Mid-buffer Redox	294
Block 3 Stream Edge Redox.....	296
Appendix D: Biological Removal Calculations	298
Block 1.....	299
Block 2.....	303
Block 3.....	306
Appendix E: Denitrification Enzyme Activity (DEA).....	310
Introduction	310
Methods.....	310
Results	316
Appendix F: Statistical Analysis.....	319
Example Code for individual Block analysis	319
SAS Output for NO ₃ -N Concentration Analysis	319
SAS Output for Cl ⁻ Concentration Analysis	330
SAS Output for NO ₃ -N/Cl ⁻ Ratio Analysis	344
SAS output for DOC Concentration Analysis.....	358
Example Code for overall analysis among different monitoring blocks.....	372
SAS output for NO ₃ -N Concentration Analysis	373
SAS Output for Cl ⁻ Concentration Analysis	379
SAS Output for Overall DOC Concentration Analysis.....	385
Appendix G: Stream Concentrations.....	393

Introduction	393
Materials and Methods	393
Results	394
Appendix H: Well Water Quality Data	396
Block 1, Transect A, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	396
Block 1, Transect A, Well Position 1(Pasture Edge), Deep Depth (3.0 m)	398
Block 1, Transect A, Well Position 2 (mid-buffer), Shallow Depth (1.5 m)	399
Block 1, Transect A, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	402
Block 1, Transect B, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	403
Block 1, Transect B, Well Position 1 (Pasture Edge), Deep Depth (3.0 m).....	404
Block 1, Transect B, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m).....	405
Block 1, Transect B, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	407
Block 1, Transect B, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	408
Block 1, Transect C, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	411
Block 1, Transect C, Well Position 1 (Pasture Edge), Deep Depth (3.0 m).....	412
Block 1, Transect C, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m).....	413
Block 1, Transect C, Well Position 2(Mid-Buffer), Deep Depth (3.0 m)	415
Block 2, Transect C, Well Position 3(Stream Edge), Shallow Depth (1.5 m)	416
Block 1, Transect C, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	418
Block 2, Transect A, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	420
Block 2, Transect A, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)	421
Block 2, Transect A, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)	422
Block 2, Transect A, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	424
Block 2, Transect A, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	426
Block 2, Transect A, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	427
Block 2, Transect B, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	429
Block 2, Transect B, Well Position 1 (Pasture Edge), Deep Depth (3.0 m).....	430
Block 2, Transect B, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m).....	432

Block 2, Transect B, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	433
Block 2, Transect B, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	435
Block 2, Transect B, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	436
Block 2, Transect B, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	438
Block 2, Transect C, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)	440
Block 2, Transect C, Well Position 1 (Pasture Edge), Deep Depth (3.0 m).....	441
Block 2, Transect C, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m).....	443
Block 2, Transect C, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	444
Block 2, Transect C, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	445
Block 2, Transect C, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	447
Block 3, Transect A, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	448
Block 3 Transect A, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)	449
Block 3, Transect A, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)	451
Block 3, Transect A, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	452
Block 3, Transect A, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	454
Block 3, Transect A, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	455
Block 3, Transect B, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	457
Block 3, Transect B, Well Position 1 (Pasture Edge), Deep Depth (3.0 m).....	458
Block 3, Transect B, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m).....	459
Block 3, Transect B, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	461
Block 3, Transect B, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	462
Block 3, Transect B, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	464
Block 3, Transect C, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m).....	465
Block 3, Transect C, Well Position 1 (Pasture Edge), Deep Depth (3.0 m).....	466
Block 3, Transect C, Well Position 2 (Mid-Buffer), Shallow Depth 1.5 m).....	468
Block 3, Transect C, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)	469
Block 3, Transect C, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)	471
Block 3, Transect C, Well Position 3 (Stream Edge), Deep Depth (3.0 m)	472

List of Tables

Table 1. Groundwater quality sampling metrics.....	40
Table 2. Block 1 soils saturated hydraulic conductivities and sand content at selected depths	51
Table 3. Monthly rainfalls for monitoring years at Enfield, NC	52
Table 4. Percent of total year water table was at or above specified depth below the ground surface for Block 1	55
Table 5. Block 1 NO ₃ -N loads for shallow (1.5 m depth) and deep (3.0 m depth) groundwater depths.....	65
Table 6. Percent of each year Block 1 redox probes at the shallow (1.5 m depth) and deep (3.0 m depth) were below the water table and percent of sampling events each year that mean redox potentials were less than 200 mV or less than 350 mV.....	67
Table 7. Block 2 Sand content and hydraulic conductivity at different depths below the ground surface.....	114
Table 8. Water table proximity to the ground surface	116
Table 9. Block 2 NO ₃ -N loads for deep 1.5 m (5 ft) and shallow 3.0 m depth groundwater	127
Table 10. Percent of each year Block 2 redox probes at the shallow (1.5 m depth) and deep (3.0 m depth) were below the water table and percent of sampling events each year that mean redox potentials were less than 200 mV or less than 350 mV.....	128
Table 11. Block 3 Sand content and hydraulic conductivity at different depths below the ground surface.....	177
Table 12. Percent of total year water table was at or above specified depth below the ground surface for Block 3.....	179
Table 13. Block 3 NO ₃ -N loads for deep and shallow wells.....	190
Table 14. Percent of each year Block 3 redox probes at the shallow (1.5 m depth) and deep (3.0 m depth) were below the water table and percent of sampling events each year that mean redox potentials were less than 200 mV or less than 350 mV.....	191
Table 15. Comparison of Physical attributes and NO ₃ -N reductions in each Block.....	237
Table 16. Percent of each year water table was at or above the specified depth for each block at the pasture edge.....	240
Table 17. Percent of each year water table was at or above the specified depth for each block at the stream edge.....	241
Table 18. Percent of mean redox potential measurements from each block that were below +200 mV or +350 mV. The probe in each block with the highest overall measurements was	

removed from this analysis. The probes removed were Block 1 mid-buffer deep, Block 2 stream edge shallow, and Block 3 stream edge shallow.....	246
Table 19. Block 1 shallow 1.5 m (5 ft) groundwater depth estimated biological removal calculations	299
Table 20. Block 1 Deep 3.0 m (10 ft) groundwater depth estimated biological removal calculations	300
Table 21. Block 2 Shallow 1.5 m (5 ft) groundwater depth estimated biological removal calculations	303
Table 22. Block 2 deep 3.0 m (10 ft) groundwater depth estimated biological removal calculations	304
Table 23. Block 3 Shallow 1.5 m (5 ft) groundwater depth estimated biological removal calculations	306
Table 24. Block 3 deep 3.0 m (10 ft) groundwater depth estimated biological removal calculations	307
Table 25. Block 1 denitrification enzyme activity rates	316
Table 26. Block 2 denitrification enzyme activity rates	317
Table 27. Block 3 Denitrification Enzyme Activity values.....	318

List of Figures

Figure 1. Riparian buffer cross-section view suggested by Welsch (1991)	3
Figure 2. Photo from May 2010 of zone 1 groundcover and zone 2 loblolly pines (<i>Pinus taeda</i>) in the background, Note the red oak (<i>Quercus rubra</i>) to right.....	28
Figure 3. Photo from May 2010 of upland pasture and zone 1 switchgrass (<i>Panicum virgatum</i>). Trees on the right side of the figure indicate the edge of zone 2.	29
Figure 4. Site aerial view and monitoring block locations	31
Figure 5. Block 1 soils at different topographic positions.....	33
Figure 6. A typical monitoring nest. From left to right: deep (3.0 m depth) groundwater monitoring well, water table logger, shallow (1.5 m depth) groundwater monitoring well, Deep and shallow redox monitoring station.	35
Figure 7. Block 1 monitoring instrumentation layout.....	36
Figure 8. Block 1 profile view and locations and depth of surficial and deep aquifer wells.	38
Figure 9. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts for 2009.	53
Figure 10. Block 1 groundwater flow directions	56
Figure 11. Block 1 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater NO ₃ -N concentrations.	59
Figure 12. Block 1 shallow (1.5 m depth) groundwater NO ₃ -N concentrations for each transect	61
Figure 13. Block 1 deep (3.0 m depth) groundwater NO ₃ -N concentrations for each transect.	62
Figure 14. Block 1 mean NO ₃ -N seasonal concentrations over the monitoring period.	63
Figure 15. Mean pasture edge redox potentials and water table elevations in 2009.	70
Figure 16. Mean stream edge redox potentials and and water table elevations in 2009.	72
Figure 17. Mean mid-buffer redox potentials and and water table elevations in 2009..	74
Figure 18. Block 1 DOC samples in deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater.	76
Figure 19. Block 1 mean seasonal DOC concentrations.	77
Figure 20. Block 1 shallow (1.5 m depth) and deep (3.0 m depth) groundwater NO ₃ -N/Cl ⁻ ratios f.....	79
Figure 21. Block 1 shallow (1.5 m depth) groundwater NO ₃ -N/Cl ⁻ ratios for each transect.	80
Figure 22. Block 1 deep (3.0 m) groundwater NO ₃ -N/Cl ⁻ ratios for each transect.....	81
Figure 23. Block 1 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater Cl ⁻ concentrations	83

Figure 24. Block 1 shallow (1.5 m depth) groundwater Cl ⁻ concentrations for each transect	85
Figure 25. Block 1 deep (3.0 m depth) groundwater Cl ⁻ concentrations for each transect....	86
Figure 26. Block 1 mean pasture edge and stream edge NO ₃ -N and Cl ⁻ concentrations in groundwater at the shallow depth (1.5 m) for each sampling date	90
Figure 27. Block 1 mean pasture edge and stream edge NO ₃ -N and Cl ⁻ concentrations in groundwater at the deep depth (3.0 m) for each sampling date	92
Figure 28. Block 1 Na ⁺ concentrations at various well depths below the ground surface. .	95
Figure 29. Block 1 Ca ²⁺ Concentrations at various well depths below the ground surface. .	97
Figure 30. Block 2 soils at different topographic locations	109
Figure 31. Block 2 monitoring well and instrumentation layout.	111
Figure 32. Block 2 profile and surficial and deep aquifer locations and depths.....	112
Figure 33. Block 2 water table elevations at the pasture edge and stream edge for 2009. ..	115
Figure 34. Block 2 flow directions	118
Figure 35. Block 2 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater NO ₃ -N concentrations.	121
Figure 36. Block 2 shallow monitoring well NO ₃ -N concentrations for each transect.	123
Figure 37. Block 2 deep monitoring well NO ₃ -N concentrations for each transect.	124
Figure 38. Block 2 mean NO ₃ -N seasonal concentrations over the monitoring period.	125
Figure 39. Block 2 mean pasture edge redox potentials and water table elevations in 2009.	130
Figure 40. Block 2 mean mid-buffer redox potentials and water table elevations in 2009.	132
Figure 41. Block 2 mean stream edge redox potentials and water table elevations in 2009.	134
Figure 42. Block 2 DOC samples in deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater.	137
Figure 43. Block 2 mean seasonal DOC concentrations.	138
Figure 44. Block 2 shallow (1.5 m depth) and deep (3.0 m depth) groundwater NO ₃ -N/Cl ⁻ ratios for each transect	141
Figure 45. Block 2 shallow (1.5 m depth) groundwater NO ₃ -N/Cl ⁻ ratios for each transect	142
Figure 46. Block 1 deep 3.0 m (10 ft) depth groundwater NO ₃ -N/Cl ⁻ ratios for each transect	143
Figure 47. Block 2 deep (D) and shallow (S) monitoring well Cl ⁻ concentrations.....	146
Figure 48. Block 2 shallow monitoring well Cl ⁻ concentrations for each transect.	148

Figure 49. Block 2 deep monitoring Cl ⁻ concentrations for each transect.....	149
Figure 50. Block 2 mean pasture edge and stream edge NO ₃ -N and Cl ⁻ concentrations in groundwater at the shallow depth (1.5 m)	153
Figure 51. Block 2 mean pasture edge and stream edge NO ₃ -N and Cl ⁻ concentrations in groundwater at the deep depth (3.0 m).	156
Figure 52. Block 2 Na ⁺ concentrations at various well depths below the ground surface ..	158
Figure 53. Block 2 Ca ²⁺ concentrations at various well depths below the ground surface .	160
Figure 54. . Block 2 soils at different topographic positions.....	173
Figure 55. Block 3 monitoring well and instrumentation layout.	174
Figure 56. Block 3 ground profile and monitoring well locations and relative depths.	175
Figure 57. Block 3 water table elevations at the pasture edge and stream edge and rainfall for 2009.....	178
Figure 58. Block 3 groundwater flow directions	181
Figure 59. Block 3 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater NO ₃ -N concentrations.	184
Figure 60. Block 3 shallow (1.5 m depth) groundwater NO ₃ -N concentrations for each transect.	186
Figure 61. Block 3 deep (3.0 m depth) groundwater NO ₃ -N concentrations	187
Figure 62. Block 2 mean groundwater NO ₃ -N seasonal concentrations over the monitoring period for shallow (1.5 m depth) and deep (3.0 m depth) groundwater at the pasture edge.	188
Figure 63. Block 3 mean pasture edge redox potentials and water table elevations in 2009. .	194
Figure 64. Block 3 mean mid-buffer redox potentials and water table elevations in 2009.	196
Figure 65. Block 3 mean stream edge redox potentials and water table elevations in 2009.	198
Figure 66. Block 3 DOC samples in deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater.	200
Figure 67. Block 3 Seasonal DOC Concentrations at different well positions.....	201
Figure 68. Block 2 shallow (S) (1.5 m depth) and deep (D) (3.0 m depth) groundwater NO ₃ -N/Cl ⁻ ratios for each transect.....	203
Figure 69. Block 3 shallow monitoring well NO ₃ -N/Cl ⁻ ratios for each transect.....	205
Figure 70. Block 1 deep (3.0 m depth) groundwater NO ₃ -N/Cl ⁻ ratios for each transect....	206
Figure 71. Block 3 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater Cl ⁻ concentrations.	208

Figure 72. Block 3 shallow (1.5 m depth) groundwater Cl ⁻ concentrations for each transect	210
Figure 73. Block 3 deep (3.0 m depth) groundwater Cl ⁻ concentrations for each transect..	211
Figure 74. Block 3 mean pasture edge and stream edge NO ₃ -N and Cl ⁻ concentrations in groundwater at the shallow depth (1.5 m) for each sampling date throughout the monitoring period	215
Figure 75. Block 3 mean pasture edge and stream edge NO ₃ -N and Cl ⁻ concentrations in groundwater at the deep depth (3.0 m) for each sampling date throughout the monitoring period	218
Figure 76. Block 3 Na ⁺ Concentrations at various well depths below the ground surface..	220
Figure 77. Block 3 Ca ²⁺ Concentrations at various well depths below the ground surface.	222
Figure 78. Site aerial view and monitoring block locations	234
Figure 79. NO ₃ -N Concentrations for each monitoring block at the buffer site.....	244
Figure 80. Dissolved organic carbon (DOC) concentrations for each monitoring block at the buffer site.....	248
Figure 81. NO ₃ -N/Cl ratios for each block a for each monitoring block at the buffer site. .	250
Figure 82. Cl ⁻ concentrations for each monitoring block at the buffer site. Lines represent trend between means at each well position.....	253
Figure 83. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2005.....	264
Figure 84. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2006.....	265
Figure 85. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2007.....	265
Figure 86. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2008.....	266
Figure 87. Mean pasture edge redox potentials and water table elevations in 2006.	267
Figure 88. Mean pasture edge redox potentials and water table elevations in 2007.	268
Figure 89. Mean pasture edge redox potentials and water table elevations in 2008.	269
Figure 90. Mean mid-buffer redox potentials and water table elevations in 2006	270
Figure 91. Mean mid-buffer redox potentials and water table elevations in 2007.	271
Figure 92. Mean mid-buffer redox potentials and water table elevations in 2008.	272
Figure 93. Mean stream edge redox potentials and water table elevations in 2006.	273
Figure 94. . Mean stream edge redox potentials and water table elevations in 2007.	274

Figure 95. Mean stream edge redox potentials and water table elevations in 2008.	275
Figure 96. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2005.	276
Figure 97. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2006.	277
Figure 98. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2007.	278
Figure 99. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2008.	279
Figure 100. Mean pasture edge redox potentials and water table elevations in 2006.	280
Figure 101. Mean pasture edge redox potentials and water table elevations in 2007.	281
Figure 102. Mean pasture edge redox potentials and water table elevations in 2008.	282
Figure 103. Mean mid-buffer redox potentials and water table elevations in 2006.	283
Figure 104. Mean mid-buffer redox potentials and water table elevations in 2007.	284
Figure 105. Mean mid-buffer redox potentials and water table elevations in 2008.	285
Figure 106. Mean stream edge redox potentials and water table elevations in 2006.	286
Figure 107. Mean stream edge redox potentials and water table elevations in 2007.	287
Figure 108. Mean stream edge redox potentials and water table elevations in 2008.	288
Figure 109. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2005.	289
Figure 110. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2006.	290
Figure 111. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2007.	290
Figure 112. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2008.	291
Figure 113. Mean pasture edge redox potentials and water table elevations in 2006.	292
Figure 114. Mean pasture edge redox potentials and water table elevations in 2007.	292
Figure 115. Mean pasture edge redox potentials and water table elevations in 2008.	293
Figure 116. Mean mid-buffer redox potentials and water table elevations in 2006.	294
Figure 117. Mean mid-buffer redox potentials and water table elevations in 2007.	294
Figure 118. Mean mid-buffer redox potentials and water table elevations in 2008.	295
.....	296
Figure 120. Mean stream edge redox potentials and water table elevations in 2007.	296
Figure 121. Mean stream edge redox potentials and water table elevations in 2008.	297

Figure 128. Mean stream NO₃-N concentrations from the upper, middle, and lower parts of the site. 395

CHAPTER 1: GENERAL INTRODUCTION

Introduction

Historical Background

Heightened concern for water quality in North Carolina developed in the late-1980s and early-1990s when surface waters in eastern North Carolina's river basins experienced several large fish kills (NCDWQ, 2002). Non-point nutrient run-off from agriculture fields in the North Carolina coastal plain was identified as one of the major contributors to the water quality problems. Stormwater from municipalities and point sources were also named as contributors. Nitrogen (N), which is an important nutrient for plant growth, has been noted as one of the primary pollutants leaving agricultural fields (NCDWQ, 2004). Nitrogen is usually applied to fields as inorganic fertilizer or animal waste. It can then be converted by microbial nitrification to nitrate (NO_3^-), a highly mobile form of N, and contaminate surface runoff or shallow groundwater under the field. Excess NO_3^- is then discharged into nearby surface waters where it can cause eutrophication and lower levels of dissolved oxygen, which when low enough can result in fish kills.

These problems led select rivers to be declared "nutrient sensitive waters" by the North Carolina Environmental Management Commission, which then required a strategy to be developed to manage the problem (NCDWQ, 2009). The first river basin to receive this designation was the Neuse followed shortly by the Tar-Pamlico. Both of these river basins extend from the piedmont of North Carolina through the coastal plain to the Pamlico Sound.

Their watersheds encompass the primary agricultural region of the state as well as several small cities.

The first component of the nutrient management strategy developed for the Tar-Pamlico river system concentrated on reducing nutrient loads to the river from point sources such as municipal waste water systems. The second phase of the strategy focused on reducing non-point nutrient contributions to the watershed, with a goal of a 30% decrease in nutrient loading from a baseline measured in 1991 (NCDWQ, 2009). New stormwater rules were implemented for towns and counties in the watershed, while nutrient management training and a county-based tracking tool were instituted for the land application of fertilizers (NCDWQ, 2009). This phase also protected the first 50 feet of existing riparian buffers within the watershed as a best management practice to reduce the discharge of nutrients into surface waters (NCDWQ, 2009). Riparian areas that were being used for crop production prior to the implementation of the rules were not protected.

Riparian Buffers

Riparian buffers are vegetated land along streams or other surface waters and are used as a best management practice (BMP) to reduce or trap potential pollutants, that originate from adjacent agricultural fields for example, before they enter surface waters. The United States Department of Agriculture (USDA) recommends a 3 zone buffer design. Zone 1 borders the stream and should extend a minimum of 4.5 m (15 ft) away from the stream. Hardwoods and other native riparian plants are planted here to stabilize the stream bank and

stream ecosystem (Welsch, 1991). This zone also improves stream habitat by helping to moderate stream temperatures through shading. Zone 2 extends a minimum of 6 m (20 ft) from zone 1 and usually contains a managed timber stand that can be harvested. Zone 1 and zone 2 may also play an integral part in the water quality benefits of buffers by providing the carbon source needed for the reduction of groundwater NO_3^- through denitrification, and providing potential vegetation uptake of nitrogen (Welsch, 1991). Zone 3 is a filter strip of grasses meant to trap sediment and associated phosphorus or pesticides bound to the sediment as it enters the buffer. Zone 3 also increases infiltration of overland runoff from the agriculture field, and should be a minimum of 6 m (20 ft) wide (Welsch, 1991). Figure 1 shows a cross-section of the different zones.

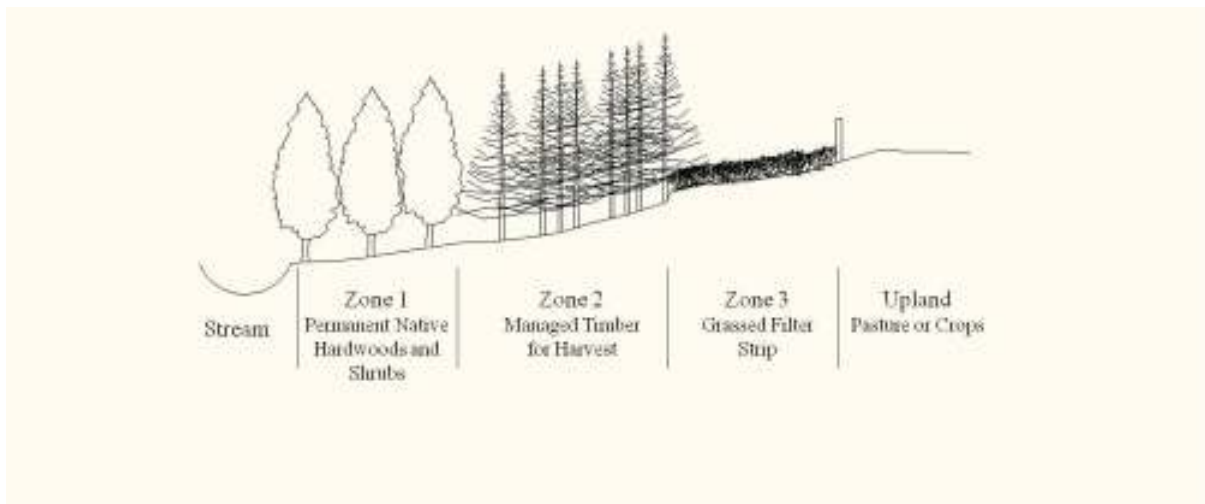


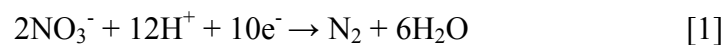
Figure 1. Riparian buffer cross-section view suggested by Welsch (1991)

Despite their use as a nonpoint source best management practice (BMP), riparian buffers have been shown to be variably effective at reducing sediment, pesticide and

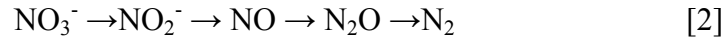
nutrients originating from agricultural lands (Lowrance et al., 1997). One of the more heavily studied contaminants is N, especially N that may pass through the shallow groundwater of the buffer system in the form of NO_3^- . Previous studies have shown that buffers can reduce NO_3^- concentrations in groundwater by as much as 75-99% (Altman and Parizek, 1995; Dukes et al., 2002; Schoonover and Williard, 2003; Vellidis et al., 2003). However, not all buffers are this effective; Clausen et al (2000) found a nitrogen concentration reduction of only 35% in the groundwater under the buffer. Dukes et al. (2002) and Snyder et al. (1998) reported ranges of 28-84% and 16-70% respectively due to variability among buffers in these studies. Several processes have been identified that are responsible for a riparian buffer's ability to remove NO_3^- from runoff and groundwater, but it is not fully understood why some buffers perform significantly better than others. The three main processes thought to reduce NO_3^- concentrations in groundwater include denitrification, groundwater mixing, and vegetation uptake, although other processes may be possible in some buffers such as dissimilatory nitrate reduction to ammonium (DNRA).

Reduction of NO_3^- Through Denitrification

Denitrification is generally thought to be the most important nitrogen removal process in riparian buffers. In this process of the N cycle, bacteria convert NO_3^- to nitrogen gas (N_2). Denitrification is a reduction reaction that generally follows the half-reaction formula of (Tesoriero et al., 1995):



During this reaction nitrogen transitions between several different molecules such as NO_3^- , nitrite (NO_2^-), nitric oxide (NO), nitrous oxide (N_2O), and finally N_2 gas as shown in equation 2 (Hochstein and Tomlinson, 1988; Martin et al., 1999; Wrage et al., 2001)



These reactions are mediated by microbial enzymes that are sensitive to environmental conditions including oxygen concentrations, organic carbon availability, NO_3^- availability, pH, and temperature (Knowles, 1982).

Most denitrifying bacteria are facultative, heterotrophic, anaerobes and prefer to use oxygen instead of nitrogen oxides as an electron acceptor since this reaction produces more energy for use by the bacteria. Enzymes associated with denitrification have been shown to be repressed when significant concentrations of oxygen are present causing the process to slow or stop (Knowles, 1982). For this reason, oxygen concentrations in groundwater must be minimal in order for the bacteria to select NO_3^- for reduction (Rivett et al., 2008).

Organic carbon is used by most denitrifying bacteria as a source of electrons in the reaction. Its availability has been found to be a limiting factor for denitrification in some riparian areas (Starr and Gillham, 1993). Low carbon availability has also been linked to increased N_2O production, suggesting that denitrifiers are not able to completely reduce the NO_3^- to N_2 gas, instead leaving it in an intermediate form (Hunt and Matheny, 2007). Typically N_2 gas is the most desirable product from the reactions since some of the intermediary gases, specifically N_2O , are considered greenhouse gases. Dissolved organic

carbon (DOC), the fraction of available carbon dissolved in groundwater, seems to be the most important form of carbon for denitrification so long as it is in a bioavailable form (Rivett et al., 2008). Baker and Vervier (2004) found that the concentration of low molecular weight carbon molecules was a more important predictor of denitrification rates in a riparian buffer than the overall DOC concentration possibly because they are more bioavailable.

Obviously, NO_3^- , or other N oxides, must be present for denitrification to occur. Very high concentrations may inhibit the reaction from proceeding to N_2 gas so that a larger fraction of intermediaries, specifically N_2O , are produced (Knowles, 1982). At very low concentrations, NO_3^- availability can be the limiting factor for denitrification rates (Knowles, 1982; Rivett et al., 2008).

Extreme pH or temperatures can also affect denitrification rates. Acidic conditions (pH <5) can inhibit denitrification enzymes and have also been found to increase the N_2O fraction, while basic conditions were found to stop denitrification above a pH value of 8.3 (Rivett et al., 2008). Similarly, extreme temperatures can slow or stop denitrification from occurring. Denitrification has been found to occur between 2-75° C, with lowered rates being reported at the cooler temperatures (Knowles, 1982; Rivett et al., 2008).

Ideally, riparian buffers are able to meet the required environmental conditions for denitrification to occur. Riparian areas often have high water tables which result in anaerobic soil conditions near the ground surface where more available carbon is likely located. Riparian vegetation can provide the needed carbon in the form of roots or surface

litter. The presence of denitrifying bacteria are generally not considered a limiting factor on the process as they are usually present in soils and groundwater (Rivett et al., 2008). While soil pH and temperature may not be optimal for denitrification rates at a particular site, they usually fall within the range where denitrification has been shown to occur.

Even when the factors mentioned above are present, in-situ denitrification rates can be highly variable depending on location in the buffer and depth in soil. Site hydrology and carbon availability seem to be the two primary factors that can affect denitrification rates in the riparian setting. Gold et al. (1998) found that denitrification rates were higher around localized areas of high carbon concentration. These high carbon areas created “hotspots” of elevated denitrification throughout the buffer. Areas with little carbon showed very little or no denitrification. Changes in hydrology throughout the year can also contribute to the variability in denitrification rates. Denitrification can only occur in those areas of the buffer where soil moisture is high enough for an extended period so that soil conditions become anaerobic or anoxic. The water table depth at the site is the major factor controlling soil moisture (Pinay et al., 1993) and water tables usually fluctuate due to seasonal variations in rainfall as well as changing evapotranspiration rates of vegetation in the buffer. Groundwater flow paths through buffers may also change due to these seasonal variations. Vellidis et al. (2003) also found that preferential flow paths of groundwater due to heterogeneous soils in riparian areas could circumvent potential denitrification areas, creating additional variability in observed rates.

Impacts of Dilution on Measured NO₃-N Concentrations in Riparian Buffers

Another process that may account for observed reductions in NO₃⁻ concentrations through riparian areas is dilution. Riparian areas are often discharge points for aquifers causing complex flow paths and mixing of formerly separated aquifers (Mengis et al., 1999). Deep aquifers or deeper groundwater flow paths below agricultural fields typically have lower N concentrations than shallow aquifers which receive fertilizer inputs directly from the land surface. If the aquifers are separated, usually by a restrictive soil layer, then the deep aquifer may be NO₃⁻ poor because its recharge area is not located where nutrients were being applied or it recharged before nutrient application began at the site. Bohlke and Denver (1995) concluded that less fertilizer was being applied at a site in Maryland when older, deep groundwater was being recharged, thus lowering the N load in the deep aquifer. If there is no separating soil layer, the slow, downward diffusion of NO₃⁻ is likely the only process for NO₃⁻ to reach the deeper groundwater flow paths. The result is similar in that deeper groundwater is often NO₃⁻ poor when compared to surficial groundwater at nutrient application sites. If the lower aquifer is relatively NO₃⁻ poor and discharges or mixes with the upper aquifer it will increase the volume of groundwater flow discharging to the stream and decrease the NO₃⁻ concentrations in the upper aquifer. This process can be mistaken for more meaningful biological removal of NO₃⁻ through the buffer.

Vegetation Uptake

Vegetative uptake in the buffer has also been proposed as one component of nitrate removal. This process will not permanently remove nitrogen from the buffer unless the

vegetation is harvested. It does, however, increase the residence time of the nitrogen in the buffer (Hefting et al., 2005). Several studies have shown that the type of vegetation has no significant effect on the effectiveness of a buffer in removing nutrients (Addy et al., 1999; Dukes et al., 2002; Hubbard et al., 1998, King and Osmond, 2005; Mayer et al., 2007; Schoonover and Willard, 2003). In contrast, Bosch et al. (1994) found evidence that during drier months when the water table is low, vegetation demand for water can contribute to an upward flow of water where it may encounter conditions more favorable to denitrification.

The most important contribution of vegetation may be related to denitrification enhancement. There is evidence that buffer vegetation may help to stimulate denitrification in the plant rhizosphere, or area surrounding the plant roots. Plant roots emit various organic compounds while they grow; these compounds can be utilized by bacteria as a carbon source for denitrification (Henry et al., 2008). In a mesocosm experiment, Henry et al. (2008) found that the addition of compounds similar to those found in plant rhizospheres approximately doubled denitrification enzyme activity and had some influence on the amount of NO and N₂O emitted.

Estimating Buffer Effectiveness

An ongoing goal for riparian buffer research has been to develop a method for simple, rapid estimation of a buffer's ability to reduce nitrogen loads to surface waters. Improvements in this area of research would enable placement of buffers where the maximum contributions to water quality would be achieved.

Hydrology is one of the major factors influencing riparian buffer effectiveness. It is often one of the most variable factors between seemingly comparable riparian buffers. Vidon and Hill (2004) proposed that the width of a riparian buffer needed to attenuate NO_3^- could be estimated using landscape and hydrologic information from the field. Their conceptual model included upland aquifer size, hydraulic conductivity of riparian soils, depth to a confining soil layer, topography, and land slope in predicting the buffer effectiveness. Vidon and Hill (2004) found that the most important factors in estimating the needed width of an effective riparian buffer were the topography of the buffer, the depth of permeable sediments in the riparian area, and the soil texture in the riparian area. They concluded that the model worked well for their study area in Southern Ontario and is probably applicable to other areas with slight modifications.

Several researchers have investigated if topography plays a role in determining the denitrification potential of a buffer (Florinsky et al., 2004; Geyer et al., 1992; Kessel et al., 1993). Topography could be easily assessed at a potential BMP site with a field visit or possibly from topographic maps. All of these studies found that the lower elevations of a landscape had the highest potential for denitrification within that BMP site, suggesting that this is where buffers should be placed. An exception occurred when a buffer site experienced dry conditions and denitrification ceased (Florinsky et al., 2004; Kessel et al., 1993). Florinsky et al (2004) used regression equations and was able to explain 45% of the variability of enzyme production and 64% of microbial biomass in the soil at different

topographic points. Their model utilized digital terrain modeling and continuous quantitative topographic parameters to predict microbe location and activity.

Similarly soil drainage class has been used to predict where maximum denitrification potentials are likely to occur within a landscape (Young and Briggs, 2007). Soil drainage class is a system developed to assess the relative wetness of soils. Young and Briggs (2007) found that poorly drained and somewhat poorly drained soils had higher potentials for denitrification than well drained or moderately well drained soils. Typically, poorly drained and somewhat poorly drained soils have higher clay contents, lower hydraulic conductivities, and often higher available carbon. However, they found that typical soil surveys were conducted on too large of a scale to accurately predict denitrification potential (Young and Briggs, 2007).

Ecosystem type has also been used to differentiate the effectiveness of buffers within a landscape. Five different ecosystem types were assessed near Lake Tahoe, Nevada for potential denitrification rates (Merrill and Benning, 2006). They found that N process rates could be distinguished among the different ecosystems which may prove useful for watershed planning or developing landscape scale N budgets.

Several researchers have developed formal assessment methodologies to predict the effectiveness of a buffer. Ducros and Joyce (2003) developed an evaluation that uses land use, slopes, vegetation type, and soil wetness to assign qualitative groups for the buffers and predict the potential benefits. Most of the parameters were drawn from literature and the

evaluation was later peer reviewed. The assessment was tested on riparian areas in the United Kingdom but the authors note that further verification using field studies is needed (Ducros and Joyce, 2003). Vidon and Dosskey (2008) also developed a method for field assessment using 8 test sites near Toronto, Canada. The assessment requires wells to be installed in a transect within the buffer and measured for nitrate concentrations for 1 day. Vidon and Dosskey (2008) found it to be effective at estimating the attenuation of nitrogen across the buffer but were unable to predict the buffer width needed for 90% nitrate removal. It is unknown if these assessments can be used in regions other than where they were developed.

The variability, both within a buffer and between buffers, has made it difficult to identify physical criteria that determine buffer effectiveness. The goal of this study is to increase the understanding of riparian buffers in North Carolina so that the North Carolina Conservation Enhancement Program will be able to better allocate its resources to those buffers that are most likely to improve water quality.

The Conservation Reserve Enhancement Program (CREP) uses state and local resources to enhance the United States Department of Agriculture's (USDA) Conservation Reserve Program (CRP) and help achieve the goals of the nutrient sensitive water management strategy. The program establishes voluntary 10, 15, 30 year and permanent contracts with landowners willing to establish conservation practices on their properties (NCDENR, 2008). CREP strongly encourages riparian buffers as a conservation practice.

Permanent contracts for forested riparian buffers usually receive the greatest incentive for establishment. In return for participating in the program, landowners receive annual land rental compensation, various tax incentives and cost-share in the establishment of their conservation practice while retaining private ownership of the land (NCDENR, 2008). The program was established in 1999 with a goal to enroll 100,000 riparian and non-riparian acres in nine river basins in Eastern and Central North Carolina (NCDENR, 2008). By accomplishing the following research objectives it is hoped that NC CREP will be able to establish those riparian buffers where they have can have the largest affect on water quality.

A NC CREP enrolled buffer was selected for evaluation in the upper coastal plain of North Carolina near the Town of Enfield. The buffer was situated along a cattle pasture that was thought to be contributing NO_3^- to a small first order stream in the Tar-Pamlico River Basin. The buffer had been planted 6 years previously, according to the design recommended by Welsch (1991). The primary source of NO_3^- in the pasture was poultry litter that was broadcast yearly as fertilizer. The overall goal of the study was to improve the understanding of riparian buffers, specifically the role buffers play in NO_3^- reductions in groundwater. The following objectives were proposed:

Objectives

1. Determine if groundwater nitrogen concentrations decrease across the buffer.
2. Identify what processes are responsible for the reduction in nitrogen concentrations.

3. Map groundwater hydrology of the site to better understand groundwater direction, gradients, and residence times.
4. Suggest specific physical aspects of the buffer that may contribute to nitrogen reduction processes occurring such as specific topography or hydrology features.
5. Make recommendations to NC CREP on the placement of riparian buffers for maximum water quality benefit

References

- Addy, K.L.; Gold, A.J.; Groffman, P.M.; Jacinthe, P.A. 1999. Ground water nitrate removal in subsoil of forested and mowed riparian buffer zones. *Journal of Environmental Quality* 28, 962-970.
- Altman, S.J. and R.R. Parizek. 1995. Dilution of nonpoint-source nitrate in groundwater. *Journal of Environmental Quality* 24, 707-718.
- Ambus, Per and Lowrance, Richard. 1991. Comparison of denitrification in two riparian soils. *Soil Science Society of America Journal* 55(4), 994-997.
- Aravena, R. and W.D. Robertson. 1998. Use of multiple isotope tracers to evaluate denitrification in ground water: Study of nitrate from a large-flux septic system plume. *Groundwater* 36 (6), 975-982.
- Baker, M.A. and P. Vervier. 2004. Hydrological variability, organic matter supply and denitrification in the Garonne River ecosystem. *Freshwater Biology* 49, 181-190.
- Böhlke, J.K. and Denver, J.M. 1995. Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland. *Water Resources Research* 31(9), 2319-2339.
- Böhlke, J.K., O'Connell, Michael E., Prestegard, Karen L. 2007. Ground water stratification and delivery of nitrate to an incised stream under varying flow conditions. *Journal of Environmental Quality* 36, 664-680.
- Bosch, D.D., Hubbard, R.K., West, L.T., Lowrance, R.R. 1994. Subsurface flow patterns in a riparian buffer system. *Transactions of the American Society of Agricultural Engineers* 37(6), 1783-1790.
- Christensen, T.H., Bjerg, P.L., Banwart, S.A., Jakobsen, R., Heron, G. Albrechtsen, H. 2000. Characterization of redox conditions in groundwater contaminant plumes. *Journal of Contaminant Hydrology* 25, 165-241.
- Clausen, J.C., Guillard, K., Sigmund, C.M., Dors, K. Martin. 2000. Water quality changes from riparian buffer restoration in Connecticut. *Journal of Environmental Quality* 29(6), 1751-1761.

- Ducros, C.M. and C.B. Joyce. 2003. Field-based evaluation tool for riparian buffer zones in agricultural catchments. *Environmental Management* 32(2), 252-267.
- Dukes, Michael D; Evans, Robert O. 2006. Impact of agriculture on water quality in the North Carolina middle coastal plain. *Journal of Irrigation and Drainage Engineering* 132 (3), 250-252.
- Dukes, M.D.; Evans, R.O.; Gilliam, J.W.; Kunickis, S.H. 2002. Effect of riparian buffer width and vegetation type on shallow groundwater quality in the middle coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers* 45(2), 327-336.
- Florinsky, I.G., McMahon, S., and D.L. Burton. 2004. Topographic control of soil microbial activity: a case study of denitrifiers. *Geoderma* 119, 33-53.
- Geyer, D.J., Keller, C.K., Smith, J.L., and D.L. Johnstone. 1992. Subsurface fate of nitrate as a function of depth and landscape position in Missouri Flat Creek watershed, USA. *Journal of Contaminant Hydrology* 11, 127-147.
- Gillham, R.W., R.C. Star, D.J. Miller. 1990. A Device for in-situ determination of geochemical transport parameters. *Groundwater* 28 (6). 858-862.
- Gold, A.J., P.A. Jacinthe, P.M. Groffman, W.R. Wright, and R.H. Puffer. 1998. Patchiness in groundwater nitrate removal in a riparian forest. *Journal of Environmental Quality* 27, 146-155.
- Hefting, Mariet M.; Clement, Jean-Christophe; Bienkowski, Piotr; Dowrick, David; Guenat, Claire; Butturini, Andrea; Topa, Sorana; Pinay, Gilles; Verhoeven, Jos T.A. 2005. The role of vegetation and litter in the nitrogen dynamics of riparian buffer zones in Europe. *Ecological Engineering* 24(5), 465-482.
- Henry, S., S. Texeier, S. Hallet, D. Bru, C. Dambreville, D. Chèneby, F. Bizouard, J.C. Germon, and L. Philippot. 2008. Disentangling the rhizosphere effect on nitrate reducers and denitrifiers: Insight into the role of root exudates. *Environmental Microbiology* 10(11), 3082-3092.
- Hill, A.R. 1996. Nitrate removal in stream riparian zones. *Journal of Environmental Quality* 25, 743-755.

- Hochstein, L.I., Tomlinson, G.A. 1988. The enzymes associated with denitrification. *Annual Review of Microbiology* 42, 231-261.
- Hubbard, R.K.; Newton, G.L.; Davis, J.G.; Lowrance, R.; Vellidis, G.; Dove, C.R. 1998. Nitrogen assimilation by riparian buffer systems receiving swine lagoon wastewater. *Transactions of the American Society of Agricultural Engineers* 41(5), 1295-1304.
- Hunt, P.G., T.A. Matheny, and K.S. Ro. 2007. Nitrous oxide accumulation in soils from riparian buffers of a coastal plain watershed – carbon/nitrogen ratio control. *Journal of Environmental Quality* 36, 1368-1376.
- Kessel, C.V., Pennock, D.J., and R.E. Farrell. 1993. Seasonal variations in denitrification and nitrous oxide evolution at the landscape scale. *Journal of the Soil Science Society of America* 57, 988-985.
- King, S.E., D.L. Osmond. 2005. Riparian buffer effectiveness in removing groundwater nitrate as influenced by vegetative type. M.S. Thesis. North Carolina State University: Raleigh, NC.
- Knowles, R., 1982. Denitrification. *Microbiological Reviews* 46 (1), 43-70.
- Kralova, M., P.H. Masscheleyn, C.W. Lindau, W.H. Patrick, Jr. 1992. Production of dinitrogen and nitrous oxide in soil suspensions as affected by redox potential. *Water, Air, and Soil Pollution* 61, 37-45.
- Larsen, D., R.W. Gentry, and D.K. Solomon. 2002. The geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA. *Applied Geochemistry* 18, 1043-1063.
- Lowrance, Richard; Sheridan, Joseph M. 2005. Surface runoff water quality in a managed three zone riparian buffer. *Journal of Environmental Quality* 34, 1851-1859.
- Lowrance, R; Vellidis, G; Wauchope, R.D.; Gay, P; Bosch, D.D. 1997. Herbicide transport in a managed riparian forest buffer system. *Transactions of the American Society of Agricultural Engineers* 40(4), 1047-1057.
- Martin, T.I.; Kaushik, N.K.; Trevors, J.T.; Whiteley, H.R. 1999. Review: Denitrification in temperate climate riparian zones. *Water, Air, and Soil Pollution* 111, 171-186.

- Mayer, P.M., S.K. Reynolds, Jr., M.D. McCutchen, and T.J. Canfield. 2007. Meta-analysis of nitrogen removal in riparian buffers. *Journal of Environmental Quality* 36, 1172-1180.
- Mengis, M.; Schiff, S.L.; Harris, M.; English, M.C.; Aravena, R.; Elgood, R.J.; MacLean, 1999. Multiple geochemical and isotopic approaches for assessing ground water NO₃⁻ elimination in a riparian zone. *Ground Water* 37(3), 448-457.
- Merrill, A.G. and T.L. Benning. 2006. Ecosystem type differences in nitrogen process rates and controls in the riparian zone of a montane landscape. *Forest Ecology and Management* 222, 145-161.
- Natural Resource Conservation Service. 2008. Web soil survey: Halifax County, NC. Available at <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>. Accessed on April 15, 2009.
- NCDENR Division of Soil and Water Conservation. 2008. Conservation Reserve Enhancement Program. Raleigh, NC: North Carolina Division of Soil and Water Conservation. Available at <http://www.enr.state.nc.us/dswc/pages/crep.html>. Accessed on November 10, 2008.
- NCDWQ. 2004. Tar-Pamlico River Basinwide Water Quality Plan. Available at http://h2o.enr.state.nc.us/basinwide/tarpam_draft_dec2003.html. Accessed on April 12, 2009.
- NCDWQ. 2002. Non-point source management program: Neuse nutrient strategy. Raleigh, NC: North Carolina Division of Water Quality. Available at http://h2o.enr.state.nc.us/nps/Neuse_NSW_Rules.htm. Accessed on November 10, 2008.
- NCDWQ. 2009. Nonpoint source management program: Tar-Pamlico nutrient strategy. Available at <http://h2o.enr.state.nc.us/nps/tarpam.htm#RuleSum>.
- Pinay, G., L. Roques, A. Fabre. 1993. Spatial and temporal patterns of denitrification in a riparian forest. *The Journal of Applied Ecology* 30 (4), 581-591.
- Phillips, Jonathan D. 1989. Nonpoint source pollution control effectiveness of riparian forests along a coastal plain river. *Journal of Hydrology* 110, 221-237.

- Puckett, L.J. 2004. Hydrogeologic controls on the transport and fate of nitrate in ground water beneath riparian buffer zones: Results from thirteen studies across the United States. *Water Science and Technology* 49(3), 47-53.
- Puckett, Larry J., Cowdery, Timothy K., McMahon, Peter B., Tornes, Lan H., Stoner, Jeffrey D. 2002. Using chemical, hydrologic, and age dating analysis to delineate redox processes and flow paths in the riparian zone of a glacial outwash aquifer-stream system. *Water Resources Research* 38(8), 1134-1154.
- Rivett, M.O., S.R. Buss, P. Morgan, J.W.N. Smith and C.D. Bemment. 2008. Nitrate attenuation in groundwater: A review of biogeochemical controlling processes. *Water Research* 42, 4215-4232.
- Schoonover, Jon E.; Williard, Karl W.J. 2003. Ground water nitrate reduction in giant cane and forest riparian buffer zones. *Journal of the American Water Resources Association* 39(2), 347-354.
- Snyder, N.J., S. Mostaghimi, D.F. Berry, R.B. Reneau, S. Hong, P.W. McClellan, and E.P. Smith. 1998. Impact of riparian forest buffers on agricultural nonpoint source pollution. *Journal of the American Water Resources Association* 34(2), 385-395.
- Spruill, Timothy B. 2000. Statistical evaluation of effects of riparian buffers on nitrate and ground water quality. *Journal of Environmental Quality* 29, 1523-1538.
- Sóvik, A.K. and P.T. Mørkved. 2007. Nitrogen isotope fractionation as a tool for determining denitrification in constructed wetlands. *Water Science and Technology* 56 (3), 167-173.
- Starr, R.C. and R.W. Gillham. 1993. Denitrification and organic carbon availability in two aquifers. *Ground Water* 31 (6), 934-947.
- Stefansson, A., S. Arnorsson, A.E. Sveinbjornsdottir. 2005. Redox reactions and potential in natural waters at disequilibrium. *Chemical Geology* 221, 289-311.
- Tar-Pamlico nutrient sensitive waters implementation strategy: Phase III. 2005. *North Carolina Environmental Management Commission Agenda Item No. 05-11*. Available at <http://h2o.enr.state.nc.us/nps/documents/PhIIIAgreementFinal4-05.pdf>.
- Tesoriero, A.J., T.B. Spruill, H.E. Mew Jr., K.M. Farrell, and S.L. Harden. 2005. Nitrogen transport and transformation in a coastal plain watershed: Influence of

- geomorphology on flow paths and residence times. *Water Resources Research* 41 (2), 1-15.
- United States Department of Agriculture Farm Service Agency. 2008. USDA and North Carolina expand CREP program fact sheet. Available at <http://www.enr.state.nc.us/dswc/pages/crepfactsheet.pdf>.
- Vellidis, G.; Lowrance, R.; Gay, P.; Hubbard, R.K. 2003. Nutrient transport in a restored riparian wetland. *Journal of Environmental Quality* 32, 711-726.
- Vepraskas, M.J. 2002. Redox potential measurements. Available at <http://www.soil.ncsu.edu/wetlands/wetlandsoils/RedoxWriteup.pdf>. Accessed on April 15, 2009.
- Vidon, P. and M.G. Dosskey. 2008. Testing a simple field method for assessing nitrate removal in riparian zones. *Journal of the American Water Resource Association* 44(2), 523-534.
- Vidon P.G. and A.R. Hill. 2006. A landscape-based approach to estimate riparian hydrological and nitrate removal functions. *Journal of the American Water Resources Association* 42 (4), 1099-1112.
- Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA-FS publication No. NA-PR-07-91. Radnor, Pa.: USDA-FS. Accessed at http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm.
- Wrage, N., G.L. Velthof, M.L. Van Beusichem, O. Oenema. 2001. Role of nitrifier denitrification in the production of nitrous oxide. *Soil Biology & Biochemistry* 33, 1723-1732.
- Young, E.O. and R.D. Briggs. 2007. Nitrogen dynamics among cropland and riparian buffers: soil-landscape influences. *Journal of Environmental Quality* 36, 801-814.

CHAPTER 2: FATE OF NITRATE AND HYDROLOGY OF MONITORING BLOCK 1

Introduction

As riparian buffers become a more important part of achieving North Carolina's water quality goals, assessing or predicting an individual buffer's contribution to water quality improvements will also become increasingly important to land planners and legislators. Rapid assessment techniques, such as those mentioned in Chapter 1, would be ideal for this purpose because they would be less expensive than in-depth field assessments at individual buffer sites. However, these rapid techniques are still being refined and adjusted for broad use, requiring researchers to depend on individual buffer investigations of soils, hydrology, and groundwater quality to determine the buffer effectiveness.

Denitrification and dilution, the major mechanisms in reducing $\text{NO}_3\text{-N}$ concentrations, have been studied at individual sites throughout the world using many different techniques. Measuring these two processes and the factors that influence them are key to understanding the effectiveness of a buffer at reducing groundwater NO_3^- concentrations.

Measuring Denitrification

Due to the complex and heterogeneous nature of riparian areas, measuring denitrification rates can be difficult. In most field studies of riparian buffers, researchers have installed groundwater wells or piezometers in transects, usually parallel to groundwater

flow paths at depths ranging from 0.6 m (2 ft) to 4 m (13 ft) below the ground surface, to monitor N concentrations as groundwater moves through the buffer (Clausen et al., 2000; Dukes et al., 2002; Hubbard et al., 1998; Mengis et al., 1999; Schoonover and Williard, 2003; Vellidis et al., 2003). If substantial denitrification is occurring in the buffer then the nitrate concentration should decrease in the monitoring wells as the groundwater moves from the upland/buffer interface toward the stream.

Other researchers have used soil cores or mesocosms to better understand denitrification in riparian areas. Ambus and Lowrance (1991) and Addy et al. (1999) removed several soil cores from riparian areas and studied them in a laboratory setting by applying solutions with known N concentrations. They found that denitrification rates tended to be higher in cores taken near the ground surface and also that rates tended to be higher in cores with more available carbon. There has been some question if laboratory soil core studies can accurately reflect in-situ conditions and variability in a natural riparian buffer setting, specifically when extrapolating rates from the laboratory to the field or landscape scale (Hill, 1996). In-situ mesocosm studies have also been devised so that a portion of the buffer can be studied in field conditions and a better estimate of in-situ denitrification rates can be obtained (Gilham et al., 1990; Mengis et al., 1999). This method allows for more accurate N balances to be calculated for in-situ conditions due to known N inputs and the defined boundaries of the mesocosm.

Measuring the isotopic fractions of NO_3^- is another method that has been used in literature to measure denitrification. Previous studies identified denitrification by utilizing the concept that the ratio of ^{15}N to other isotopes of N in NO_3^- tends to increase as denitrification occurs (Aravena and Robertson, 1998; Bohlke and Denver, 1995; Mengis et al., 1999). The studies have also used ^{18}O in NO_3^- in the same manner. Fractionation occurs because bacteria responsible for denitrification tend to select lighter isotopes of NO_3^- leaving the heavier ^{15}N and ^{18}O isotopes behind (Mengis et al., 1999). This method should allow denitrification to be identified even if groundwater mixing is occurring in the buffer (Mengis et al., 1999). It is important to note that different NO_3^- sources may have different initial $^{15}\text{N}/\text{N}$ and $^{18}\text{O}/\text{O}$ ratios (Mengis et al., 1999) and the system should stay mostly anaerobic as other aerobic N cycle processes, such as nitrification, could potentially confound ^{15}N and ^{18}O results (Sovik and Morkved, 2007). Fractionation can also be more expensive than other techniques and was not utilized in this study for that reason.

Acetylene has also been used to determine denitrification rates. Acetylene inhibits the reduction of N_2O to N_2 in the last stages of the denitrification process (Martin et al., 1999). The N_2O can be collected from the soils using sieve traps or some other enclosure capable of capturing most of the escaping gases (Knowles, 1982). After collection the denitrification rate can be determined by the rate of N_2O accumulation (Martin et al., 1999). However, some concerns remain with the technique including reports of incomplete inhibition of N_2 production in low NO_3^- concentration situations, impurities in applied acetylene increasing available carbon for denitrification, and the inhibition effect acetylene

may have on other N processes such as nitrification (Knowles, 1982; Martin et al., 1999).

Acetylene techniques tend to be focused on a small portion of a buffer for study. This can be problematic when trying to come to conclusions at the field scale as results from the technique could have missed hot or cold spots of denitrification activity causing estimations of buffer effectiveness to be high or low respectively. For this reason the technique was not used in this study.

Measuring the redox potential of the soil or groundwater is another method to determine if conditions for denitrification are present. As mentioned in Chapter 1, denitrification is a reduction-oxidation reaction that can generate a small electrical potential that can be measured in-situ using platinum electrodes and a voltmeter. In a laboratory setting, Kralova et al. (1992) found redox potential to be an important factor in determining the rate of denitrification as well as its extent of completeness. They found that denitrification was likely to occur at or below a +200 mV redox potential. Several researchers have warned against using measured redox potentials in aquifer chemical redox calculations or other quantitative analysis because natural aquifers very rarely reach equilibrium with respect to redox conditions (Christensen et al., 2000; Stefanson et al., 2005). However, the measurements can be used qualitatively to get a better understanding of where reducing conditions in the aquifer are more intense (Christensen et al., 2000).

Measuring Dilution

Groundwater mixing and flow paths can also contribute to reduced observed nitrogen concentrations and needs to be considered when determining whether NO_3^- is being removed by the buffer or diluted. Dilution has been accounted for in buffer studies by normalizing groundwater NO_3^- concentrations with Cl^- concentrations (Altman and Parizek, 1995; Dukes et al., 2002; Mengis et al., 1999; Schoonover and Williard, 2003). Chloride in groundwater likely comes from the same practices as nitrogen, fertilizers or animal wastes applied to the field (Dukes et al., 2002). However, Cl^- is considered conservative in groundwater, meaning it remains in solution in groundwater and is unaltered chemically or biologically as it moves through the aquifer (Dukes et al., 2002). Just like NO_3^- , there should be very little Cl^- present in deeper groundwater. Therefore a decreasing Cl^- concentration in shallow groundwater may indicate that deeper groundwater is mixing with shallow groundwater (Dukes et al., 2002). For example, using this technique, Schoonover and Williard (2003) reported 40% of observed NO_3^- concentration reduction at their buffer site was dilution.

Dissolved cations in groundwater can also offer clues to preferential flow paths and groundwater mixing. Unlike Cl^- , cations are rarely conservative in groundwater but they can still be used to better understand separation and flow of a groundwater system. Aquifers that are separated often have different groundwater chemistry due to interaction with different aquifer environments or because of differences in groundwater inputs at the time of recharge (Bohlke and Denver, 1995). Bohlke and Denver (1995) used major solutes, including Na^+ and Ca^{2+} , in groundwater to aid in determining recharge areas and discharge points for two

different watersheds. In a study investigating deep groundwater in a riparian zone, cations and other molecules were used to help determine flow paths (Puckett et al., 2002). Larsen et al. (2002) used similar cation solutes to help identify a large perched aquifer as well as mixing between the perched aquifer and the deeper aquifer below.

The goal of this study was to apply some of the above mentioned measurement techniques to a CREP enrolled buffer and better determine the fate of groundwater NO_3^- as it moved through the buffer. Understanding the role of denitrification and dilution at the field scale will lead to better buffer design and placement in the landscape. If individual processes can be linked to easily measurable characteristics of the buffer generalized rapid assessment techniques should become more accurate and feasible and planners will be able to better allocate resources to those buffers that are predicted to have the greatest affect on improving water quality.

Materials and Methods

Site Description

The research site was located in the upper coastal plain of North Carolina near the town of Enfield in Halifax County. The buffer was positioned along Ruth's Branch, a small 1st order stream that discharges into Fishing Creek, in the Tar-Pamlico watershed. The North Carolina Division of Water Quality (NCDWQ) identified the Fishing Creek sub-basin of the Tar-Pamlico as a targeted watershed for best management practices and restoration efforts (NCDWQ, 2004). The buffer was established and planted in 1999 and was planted according

to the 3-zone design recommended by the USDA (Welsch, 1991). Zone 1 was adjacent to the stream and averaged about 12 m (40 ft) wide. The primary vegetation was Northern Red Oak (*Quercus rubra*) which was planted at the site during the establishment of the buffer (Figure 2). Colonizers included American Sweet Gum (*Liquidambar styraciflua*), fescue grass, roundleaf greenbrier (*Smilax rotundifolia* L.), and the invasive Japanese Stilt grass (*Microstegium vimineum*). A vegetation survey completed at the end of the project found that hardwood diameters ranged from about 15 cm (6 in) to 1 cm (0.5 in) with Red Oaks comprising a majority of the smaller diameters.



Figure 2. Photo from May 2010 of zone 1 groundcover and zone 2 loblolly pines (*Pinus taeda*) in the background, Note the red oak (*Quercus rubra*) to right.

Zone 2 was planted with Loblolly Pine (*Pinus taeda*) and extended 21 m (70 ft) upslope. Pine diameters ranged from about 28 cm (11 in) to 5 cm (2 in). Zone 3 encompassed the area between the pasture edge and Zone 2 and was about 12 m (40 ft) wide. It was planted with Switchgrass (*Panicum virgatum*) but fescue was also present (Figure 3).



Figure 3. Photo from May 2010 of upland pasture and zone 1 switchgrass (*Panicum virgatum*). Trees on the right side of the figure define the edge of zone 2.

The buffer at the site was about 850 m (2800 ft) long with an average width of 46 m (150 ft). Figure 4 shows an aerial view of the buffer and the approximate locations of the blocks where the buffer was monitored. The headwaters of the stream began northwest of the most upstream Block 3, about 120 m (400 ft) upstream from the area shown in Figure 4.

Block 1 was the most downstream and lowest elevation monitoring block at the site. The stream was 0.6 -1.2 m (2-4 ft) wide and was incised between 1.2-1.5 m (4-5 ft) along Block 1. The floodplain for the stream was easily identifiable with a 0.6-1.2 m (2-4 ft) increase in elevation about 33 m (110 ft) from the stream bank. The upland land use was pasture for grazing beef cattle and had a slope of about 0.045. The pasture had a contributing area of about 2.5 ha for Block 1 and was fertilized in February or early March of each year. Fertilization consisted of broadcasted poultry litter at a rate of approximately 2,200 kg/ha. Using guidance documents from the North Carolina Cooperative Extension Service (Zublena et al., 1996) an application of 41 kg-N/ha was calculated. Grazing cows in the pasture were a source of additional N inputs to the groundwater moving through the site.

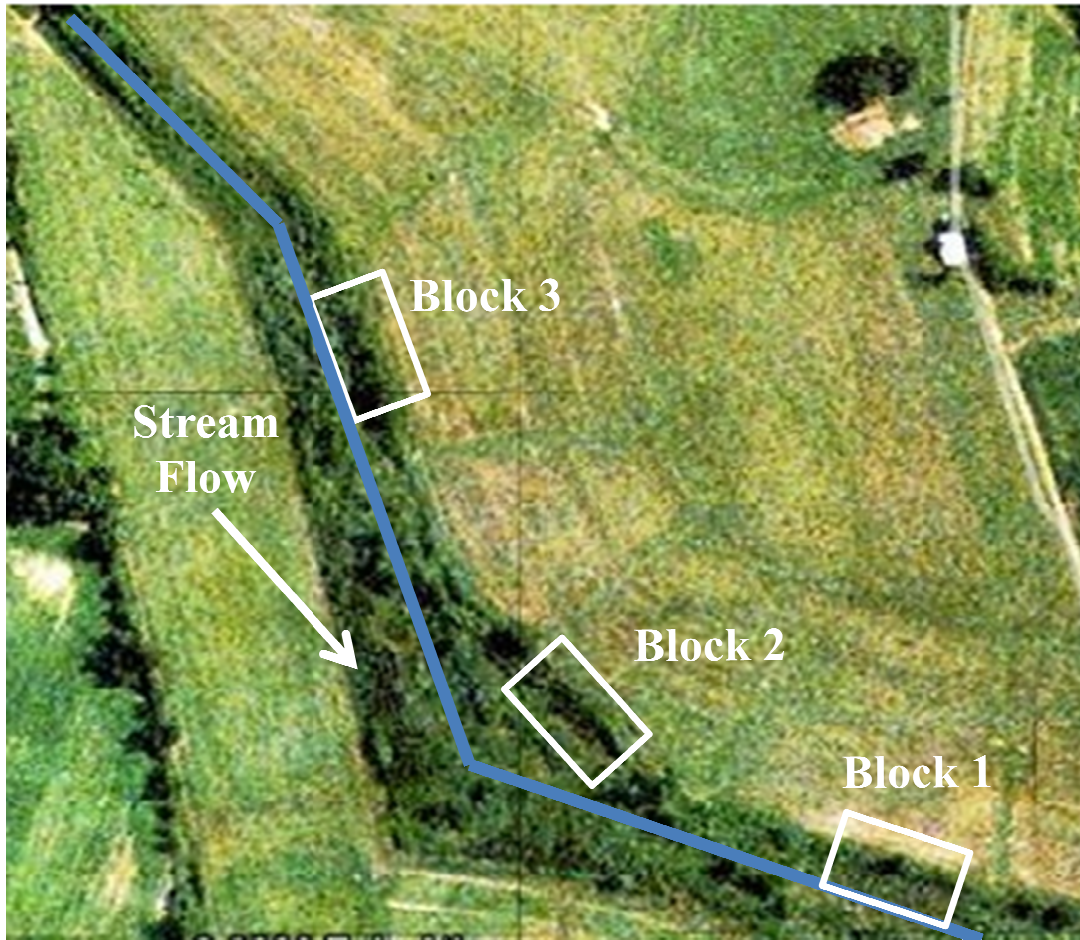


Figure 4. Site aerial view and monitoring block locations

Soils Description

The NRCS soils survey (NRCS, 2008) indicated that the primary soil types in the pasture were Bonneau loamy fine sand and Emporia-Wedowee sandy loam complex.

Bonneau soils were classified as loamy, siliceous, thermic, Arenic Paleudults. The Emporia and Wedowee were classified as fine-loamy, siliceous, subactive, thermic Typic Hapludults and fine, kaolinitic, thermic Typic Kanhapludults respectively. Inside the buffer the soils were Goldsboro fine sandy loam described as fine, loamy siliceous subactive thermic Aquic

Paleudults. The survey indicated that all of these soils were moderately well drained to well drained and had a moderate to high capacity to transmit groundwater.

Field verification indicated the soils in the pasture upslope from the buffer consisted of a silty clay or silt above a silt saprolite that occurred at about 1.5-2.5 m (5-8 ft) below the surface. The saprolite continued until auger refusal at about 9.6 m (32 ft).

Inside the buffer, Block 1 had a sand to silty sand surface layer with rounded gravels throughout indicating that this layer was likely alluvial. At 3.0-4.0 m (10-13 ft) below the ground surface a clay saprolite horizon, similar to the deep horizons found in the pasture, began and continued to the bottom of the borings at about 6 m (20 ft). Figure 5 shows the textures of soils at different elevations and locations within Block 1.

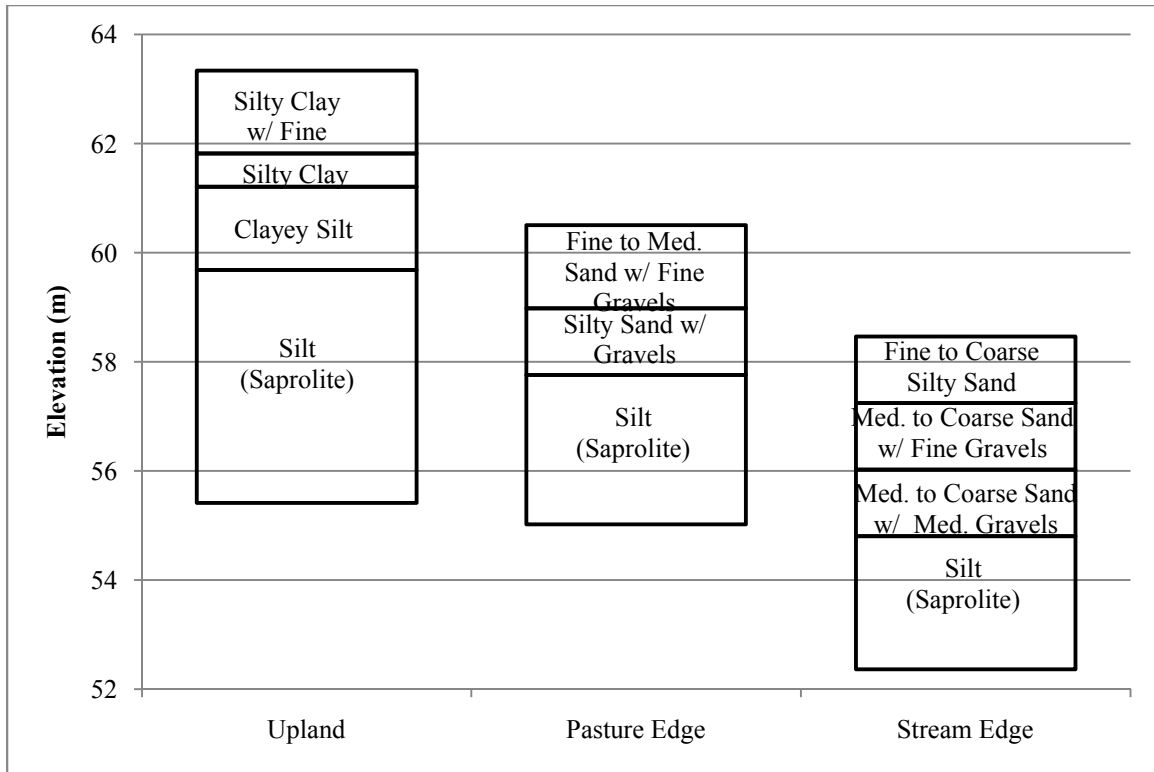


Figure 5. Block 1 soils at different topographic positions

Groundwater Monitoring

Prior to groundwater well installation the direction of groundwater flow was inspected to ensure that groundwater was moving from the uplands, through the buffer, and to the stream. After the installation of some preliminary groundwater monitoring wells, the three-point method (Swartz and Zhang, 2003) was used to determine the direction of groundwater flow. Groundwater wells in the monitoring block were then oriented to be approximately parallel to the direction of groundwater flow.

Block 1 was designed to contain three transects perpendicular to the stream, spaced 30 m (100 ft) apart (labeled A, B, and C in Figure 6.). Each transect contained a well nest at the pasture edge, mid-buffer, and at the stream edge (labeled 1, 2, and 3 respectively in Figure 6). The pasture edge well nest was located at the interface of the buffer and pasture within zone 3 approximately 46 m (150 ft) from the stream. The mid-buffer wells averaged 23 m (75 ft) from the stream and located in the middle of zone 2. Stream edge wells were within a 4 m (13 ft) of the stream in zone 1. Each well nest contained a deep and shallow surficial groundwater monitoring well except in transects A and B at the mid-buffer well position and transect A at the stream edge. Only shallow wells were installed at these locations due to difficulties in reaching the required depth for deep wells. Plots in this chapter may have select water quality data removed to improve clarity. The location of the removed data will be noted in the caption under each graph using the following method: PE denotes pasture edge (well position 1), MB denotes the mid-buffer (well position 2), and SE denotes the stream edge (well position 3). The depth of each well was also included with S denoting the shallow depth (1.5 m depth) and D denoting the deep depth (3.0 m).

An Infinity® pressure transducer and datalogger continually logged the water table depth in wells located near the pasture edge (USDA - Zone 3) and within 1.5 m of the stream edge (USDA - Zone 1).



Figure 6. A typical monitoring nest. From left to right: deep (3.0 m depth) groundwater monitoring well, water table logger, shallow (1.5 m depth) groundwater monitoring well, Deep and shallow redox monitoring station.

Surficial wells were installed at the site in November 2004. These wells consisted of 5 cm (2 in) diameter PVC installed to a maximum depth of 3-3.7 m (9-11 ft) for the deep wells and 1.5-2.1 m (5-7 ft) for the shallow wells. Throughout this document the terms deep groundwater and shallow groundwater and 3.0 m (10ft) and 1.5 m (5 ft) depth groundwater refer to the groundwater flowing by these surficial wells. The screens were 0.6 m (2 ft) long and consisted of 1 cm (0.4 in) drilled holes at 15 cm (6 in) spacing and covered with a fabric

drain sock to prevent soil intrusion. The void space around the wells were backfilled with sand to the top of the screen and then with bentonite to slightly above the ground surface.

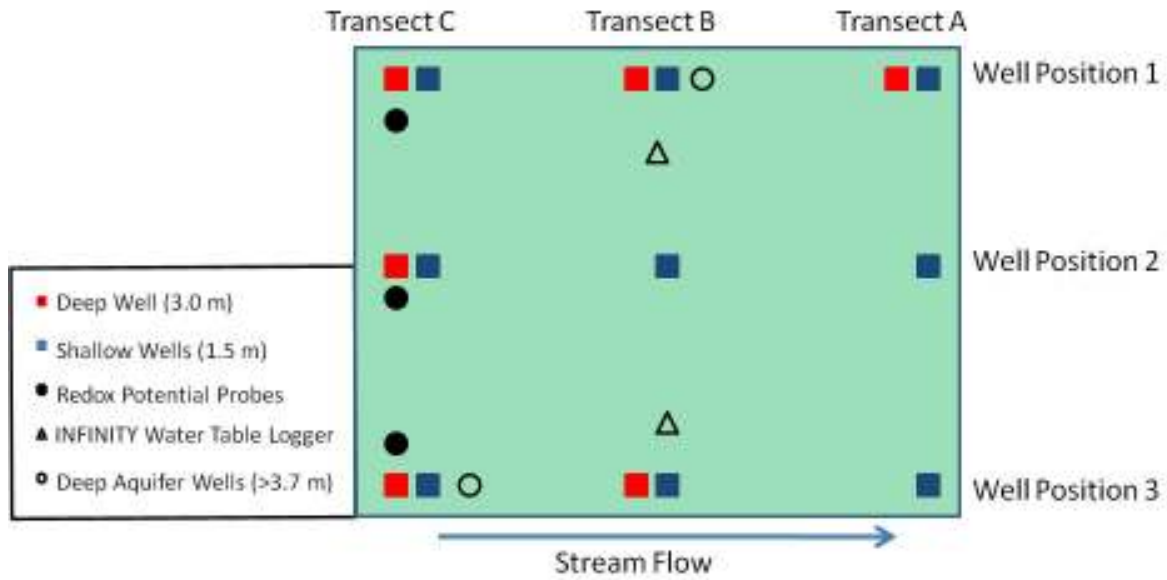


Figure 7. Block 1 monitoring instrumentation layout

Three deep aquifer wells were also installed at various depths in June 2008 in or near Block 1. One was located in the pasture just upgradient of Block 1 between Blocks 1 and 2. A deep well was also located at the pasture edge and along the stream edge in transects B and C respectively. The goal was to assess the chemistry of deeper groundwater in order to gage the amount of mixing with the surficial groundwater. Figure 7 shows a profile of Block 1 and the locations and relative depths of the surficial and deep aquifer wells.

Deep aquifer wells were installed by a North Carolina Division of Water Quality well installation team using a GeoProbe™ Direct Push Auger. The depth of installation was

determined by assessing the soil layers at each well location. The wells were placed in the deep saprolitic layer (see Figure 5 and Figure 7), usually about a meter below where the layer first began. At the pasture edge the well was screened between 3.7-5.2 m (12-17 ft) below the ground surface while at the stream edge the deep aquifer well was screened at 4.4-5.9 m (14.5-19.5 ft). The wells were 1.9 cm ($\frac{3}{4}$ in nominal) diameter PVC, with a 1.5 m (5 ft) pre packed screen section at the desired depth. The pre-packed screen consisted of a normal slotted PVC screen surrounded by sand and a stainless steel well screen. A 1.2 m (4 ft) bentonite insulated pipe section was attached above the screen to ensure that the surficial and deep groundwater remained separated. The remaining pipe was backfilled with granular bentonite to the surface where a 1 m (3.5 ft) metal casing was installed around the well riser for protection.

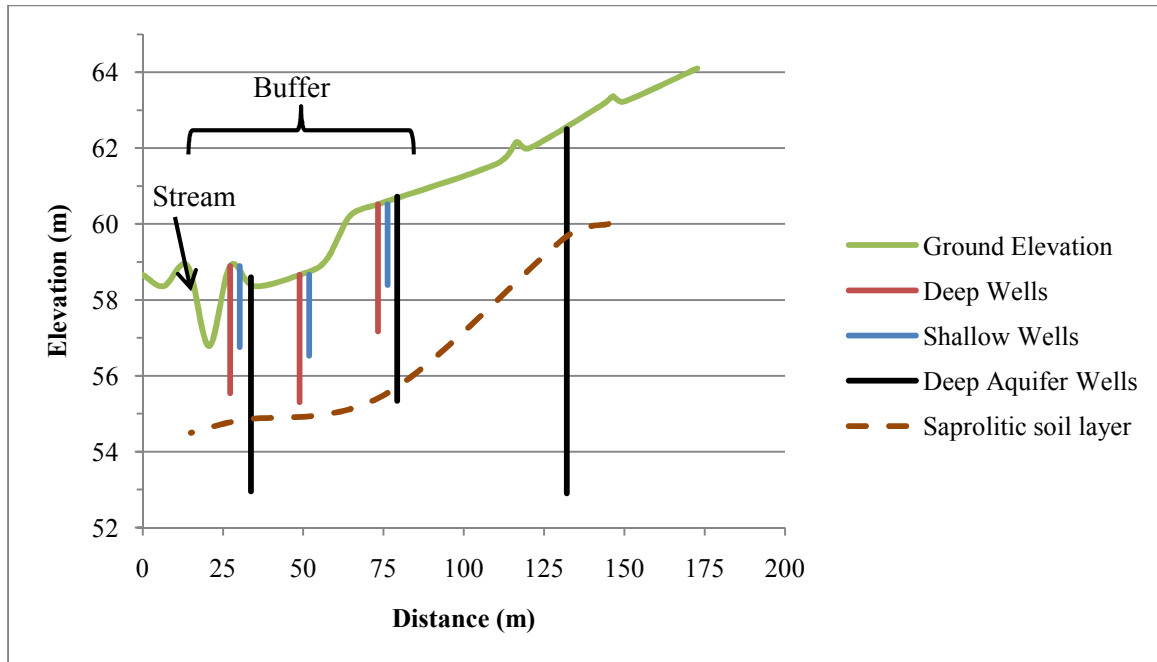


Figure 8. Block 1 profile view and locations and depth of surficial and deep aquifer wells.

Groundwater Quality Sampling

Table 1 shows the metrics, the location and the frequency of groundwater sampling that were used in the analysis of this thesis. Total kjeldahl nitrogen (TKN), total phosphorus (TP), phosphate (PO_4) and total organic carbon (TOC) were also analyzed during periods of the project. Both TKN and TP were sampled from 1/12/2005 to 7/13/2005 and PO_4 was sampled from 1/12/2005 to 6/10/2008. These analysis were suspended after it was obvious that concentrations in the groundwater were small and constant throughout the year. The TOC sampling began on 3/10/2005 extended to 6/10/2008 and was stopped in favor of DOC sampling.

All wells were sampled on a monthly basis. Wells were purged prior to sampling, using 12V submersible pumps, until no more water could be evacuated or until 3 well volumes had been removed. The wells were allowed to recharge and then were sampled using a polyethylene bailer on a retrieval leash. The sample was then poured into two 500 mL bottles and placed on ice in a cooler for transport. The first sample was used for nutrient analysis ($\text{NO}_3\text{-N}$, NH_4^+ , Cl^-) and were acidified with H_2SO_4 to preserve the sample. The second sample was used for cations (Na^+ and Ca^{2+}) and dissolved organic carbon analysis and was not acidified. All analysis was performed by the North Carolina State University Biological and Agricultural Environmental Analysis Laboratory.

Table 1. Groundwater quality sampling metrics

Metric	Sampling Location	Frequency	Analysis Method
NO ₃ -N	All Wells	Monthly	EPA 353.2
Cl ⁻	All Wells	Monthly	EPA 325.2
NH ₄ ⁺	All Wells	1/05 - 2/09: Monthly, 2/09-5/10: Quarterly	EPA 351.2
DOC	All Wells	8/08 - 5/10: Every 2 months	EPA 415.1
Na ⁺ and Ca ²⁺	Deep Aquifer Wells, Pasture Edge and Stream Edge Surficial Wells	Monthly	EPA 200.7

Water Table Measurements

Water level data loggers (Infinities® USA, Port Orange, Florida) were installed at the pasture edge and stream edge (see Figure 6) to log water table depth on an hourly basis in each block. The loggers were placed in a casing that was constructed of 5 cm (2 in) screened PVC and installed to a depth of 3.7 m (12 ft). The void space around the casings was backfilled with sand and capped with bentonite at the surface. The Infinity loggers were downloaded using an HP 48 G+ calculator on a monthly basis.

Water table elevation was also measured manually in the water level monitoring wells and in all water quality monitoring wells on a monthly basis. A hand-held water level meter (Solinst® Model 101) was used to take manual measurements from a marked reference point on each well to the top of the phreatic zone inside the well. These measurements were used to calibrate data loggers, while measurements made in the water quality wells provided a

monthly snapshot of the water table profile across the entire block to assess groundwater flow direction.

Soil Sampling

Soils were sampled for denitrification enzyme activity (DEA) and particle size within each monitoring block. The DEA analysis provided potentially valuable information of the presence of microbes capable of denitrification in the soils, while particle size analysis was useful for estimating saturated hydraulic conductivity and permeability of the soils.

The soil samples were collected in February 2009 and September 2009 for DEA analysis. In Block 1, samples were taken alongside wells in Transect A and Transect C at each of the three well positions. Samples were collected using a hand auger from depths of approximately 30 cm, 50cm, and 80 cm for each sampling position. Samples were placed in plastic bottles, and then on ice in a cooler. They were then shipped in a cooler with ice packs to the USDA Agricultural Research Service labs in Tifton, Georgia for analysis.

Soil samples for particle size analysis were collected in November 2004 and September 2009 at the monitoring site. The first sample collection occurred when the wells were being installed. Soil samples were collected for each monitoring well at approximately the depth that the well screen was installed, usually about 180 cm for shallow wells and 330 cm for deep wells. Notable soil features, such as restrictive layers, that were encountered were also sampled. Only the Transect B samples and notable soil features were analyzed for particle size. Samples were placed in plastic bags and analyzed at the North Carolina State

University Soil Science Laboratory. During the October 2009 event samples were collected in the upland, and each zone of the buffer along the middle transect of the monitoring block. Samples were collected at depths of 30 cm, 50cm, and 80 cm using hand augers, placed in plastic bags, and transported to the North Carolina State University Soil Science Laboratory for analysis.

To obtain saturated hydraulic conductivities for the site, the auger hole method (Van Beers, 1970) was first attempted. Due to difficulties associated with low water tables at the site, the method was abandoned for the Soil-Pond-Atmosphere-Water (SPA-W) Field and Pond Hydrology model (Saxton, version 6.02.75) derived from research by Saxton and Rawls (2006). Using the soil-water characteristics function and the information gained from the particle size analysis, hydraulic conductivities of individual samples were estimated.

Rainfall Measurements

Rainfall was measured at the site with a tipping bucket rain gage and HOBO datalogger (Onset Computer Corp®, Cape Cod, MA). A manual rain gage was also located at the site and was measured twice a month to ensure tipping bucket accuracy. Both gages were located near the middle of the buffer and away from trees and other obstructions. Data from an Enfield, NC weather station (Station # 312827) was also obtained through the State Climate Office of North Carolina (<http://www.nc-climate.ncsu.edu/services/request.php>) to ensure accuracy and fill data gaps if the tipping bucket rain gage malfunctioned.

Redox Potential Probes

Platinum-tipped probes used to measure in-situ soil redox potential were constructed according to Wafer et al. (2004). Five individual probes were grouped in 5 cm (2 in) PVC pipe and sealed with end caps and silicon. Only the platinum tip of the probe was exposed to the soil through small holes in the end cap. Within the monitoring block, two of the probe groups were placed at each of the well positions (Figure 6). Stations were placed in transect C due to the difficulties of installing wells in transect B. One probe group was installed at the deep well depth (2.7 – 3.4 m) and one at the shallow well depth (1.5 – 2.1 m).

Probes installation and monthly monitoring of potentials began in September 2006. Potentials were measured using a Fisher Scientific ® Accumet AP62 Portable meter and a portable KCl saturated Ag/AgCl reference electrode (Jensen Instruments, Tacoma, Wa). The five potentials measured at each location were averaged for each event. A +204 mV correction factor was applied to all field measurements to adjust for pH and to correct for differences in the Ag/AgCl electrode and the hydrogen electrode standard at 20° Celsius (Fiedler et al., 2007).

Site Survey

A previous survey in 2005 was conducted that primarily collected locations and elevations of monitoring wells and other instrumentation within the buffer. In March 2009 a second survey was completed for the locations of the newly installed deep aquifer wells, the topography of the buffer and uplands, and to verify points taken in the earlier survey. Each

survey was completed using an Electronic Total Station (Topcon®, Livermore, CA) and then imported into AutoCAD® software (AutoDesk, San Rafael, CA) for analysis and map creation. All elevation data used in analysis was obtained from these two surveys. No elevation monuments could be located in the area so all surveying elevations were related to a benchmark that was given an elevation of 61 m (200 ft). USGS topographic maps (Ringwood, NC 2010) of the site showed that this would have been very close to the actual elevations.

Flux and load Calculations

Nitrate-nitrogen loads were calculated for the monitoring period for both the shallow and deep surficial monitoring wells.

First the Dupuit-Forchheimer assumptions were applied to Darcy's law to calculate the total flow rate between the pasture edge and stream edge of each monitoring block:

$$Q_T = \frac{K_e W}{2L} (h_{pe}^2 - h_{se}^2) \quad [3]$$

where

Q_T = total flow rate (cm³/hr)

K_e = effective saturated hydraulic conductivity (cm/hr)

W = width between the monitoring wells (cm)

L = length of the flow path (cm)

h_{pe} = water table height above the datum at the pasture edge (cm)

h_{se} = water table height above the datum at the stream edge (cm)

The effective saturated hydraulic conductivity was calculated using the saturated hydraulic conductivities found from the particle size analysis at the 180 cm and 330 cm depths (see Table 2). The width between the monitoring wells was 3,048 cm (100ft) and the length of the flow path was the distance between the water table loggers at the pasture edge and stream edge (4,190 cm or 137 ft). The vertical datum used for the calculation was the approximate elevation of the saprolitic layer mentioned in the soils description of 53.9 m (177 ft).

Next the same formula was applied to calculate the flow that occurred at depths above the deep wells by raising the datum to an elevation of 55.7 m (183 ft). This would be the flow rate associated with shallow well concentrations when calculating loads.

$$Q_{SL} = \frac{K_e W}{2L} (h_{pe}^2 - h_{se}^2) \quad [4]$$

where

Q_{SL} = flow rate of the shallow layer (cm³/hr)

\ K_e = effective saturated hydraulic conductivity (cm/hr)

W = width between the monitoring wells (cm)

L = length of the flow path (cm)

h_{pe} = water table height above the datum at the pasture edge (cm)

h_{se} = water table height above the datum at the stream edge (cm)

For this formula, the effective saturated hydraulic conductivity was calculated using only those conductivities that were found at the 180 cm depth since that is the approximate depth

of the shallow monitoring wells. All other parameters were the same as those used in Equation 3.

In order to obtain the deep layer flow rate, the flow rate associated with the deep monitoring wells, the shallow layer flow, Q_{SL} , was subtracted from the total flow, Q_T :

$$Q_{DL} = Q_T - Q_{SL} \quad [5]$$

where

Q_{DL} = flow rate of the deep layer (cm^3/hr)

Q_T = total flow rate (cm^3/hr)

Q_{SL} = flow rate of the shallow layer (cm^3/hr)

The volumetric flow rates for both the shallow layer and deep layer were calculated on an hourly basis. These rates were then averaged for the sampling period corresponding to the water quality sampling event. The sampling period included the date of the groundwater sampling and all days after until the next sampling event occurred. Not all sampling periods were the same length due to changes in sampling schedules or missed sampling events. However, the average sampling period was about 699 hrs (29 days), which was only slightly less than the monthly sampling period goal. If the well was dry during the sampling event or a water quality sample was unable to be taken from the well, then no load was calculated for that sampling period. The result was an average volumetric flow rate (Q_{avg}) for the deep and shallow layers that could be associated with each water quality sample that was collected.

The average mass flow rate, Q_m (mg/hr), of NO_3^- -N was then found by using the following formula:

$$Q_m = 0.001 Q_{avg} C \quad [6]$$

where

Q_{avg} = volumetric flow rate that has been averaged for the sampling time period (cm^3/hr)

C = concentration of NO_3^- -N obtained from groundwater sampling events (mg/L)

0.001 = factor for converting cm^3 to liters (L/cm^3)

Finally the load was calculated by multiplying the sampling time period by the average mass flow rate to obtain the load, L (kg), for that sampling period:

$$L = 0.000001 Q_m T \quad [7]$$

where

Q_m = average mass flow rate (mg/hr)

T = sampling event time period (hrs)

0.000001 = factor for converting mg to kg

These loads were then summed for yearly or seasonal load values. To obtain the load on a per hectare basis the loads were divided by the contributing area of the buffer. It should be noted that these calculations do not account for any additional water that may have been added to the soil layer from upwelling or groundwater mixing.

Residence Time Calculations

Residence time is the amount of time that flowing groundwater is expected to remain within the boundaries of the buffer. A longer residence time may increase the potential for denitrification to occur in the groundwater because the likelihood of the water encountering a reducing area in the buffer also increases. Residence time was calculated by assuming steady flow and applying the Dupuit-Forchheimer assumptions to Darcy's law in the formula:

$$Q = \left[\frac{K_e}{2L} (h_{pe}^2 - h_{se}^2) \right] / n \quad [8]$$

where

Q = rate per unit width of the buffer (cm²/hr/cm)

K_e = effective saturated hydraulic conductivity (cm/hr)

L = length of the flow path (cm)

h_{pe} = elevation above the datum logged by the pasture edge water table datalogger (cm)

h_{se} = elevation above the datum logged by the stream edge water table datalogger (cm)

n = porosity of the soils (unitless)

The length of the perpendicular flow path (L) from the buffer edge to the stream was 4600 cm (150 ft) which corresponded to the average width of the buffer. Saturated hydraulic conductivities and porosities were obtained using the particle size analysis samples and

USDA database (Rawls et al. 1998) and then calculating composite values across all well positions and depths.

The flow rate (Q) was then divided by the depth to the restrictive soil layer to find the flux (q) in velocity units (cm/hr). In these calculations the restrictive layer was considered the saprolitic soil layer that occurred at approximately 400cm (13ft) below the ground surface. The maximum, minimum, mean and median fluxes were found and applied to the following formula so that a range of residence times could be determined:

$$t = \frac{L}{q} \quad [9]$$

where

t = residence time (hr)

L = flow path length (cm)

q = seepage flux (cm/hr)

Statistical Methods

Statistical analysis was performed to determine if there were differences between the groundwater constituents at different well positions within each monitoring block. The “proc mixed” procedure was used in SAS 9.1® (SAS Institute, Cary, NC) with well position and depth used as the fixed effect and transect and transect*well position as random effects. The natural log of NO₃-N, Cl⁻, DOC concentrations and NO₃-N/Cl⁻ ratios were analyzed individually as response variables. The log was applied due to not normal distribution of

residuals. An auto regressive (AR(1)) model was also included. Mean separation was tested at the $\alpha = 0.05$ significance level.

The natural log of Na^+ and Ca^{2+} were also analyzed using the same procedure except that well depth was used as the fixed effect instead of well position.

Results

Particle Size and Hydraulic Conductivity

Measurements using the auger hole method were only obtained at the mid-buffer due to difficulties in reaching the low water table. A saturated hydraulic conductivity of 18.7 cm/hr was calculated for the mid-buffer. This method was abandoned for the Soil-Pond-Atmosphere-Water (SPAW) Field and Pond Hydrology model because more measurements were needed from the other sections of the buffer. Using the soil-water characteristics function and the information gained from the particle size analysis accurate hydraulic conductivities of individual samples were made.

Table 2 shows the sand content and saturated hydraulic conductivities calculated for in Block 1. Overall, the soils had high sand contents with some layers of less conductive material throughout. The 180 cm and 330 cm depths corresponded to approximately the mid-point in the well screens for the shallow and deep wells.

Table 2. Block 1 soils saturated hydraulic conductivities and sand content at selected depths

Depth Below Ground Surface	Pasture Edge		Mid-Buffer		Stream Edge	
	Sand (%)	Hydraulic Conductivity (cm/hr)	Sand (%)	Hydraulic Conductivity (cm/hr)	Sand (%)	Hydraulic Conductivity (cm/hr)
30 cm	91	14.6	63	4.9	81	11.6
50 cm	92	14.7	87	12.8	92	13.3
80 cm	89	14.4	94	15.2	90	14.3
180 cm	74	4.4	82	3.6	65	0.7
330 cm	42	0.9	39	0.5	86	5.5

Rainfall

According to the State Climate Office of North Carolina mean annual rainfall in Enfield, NC is 1,154 mm (45.5 in). Table 3 shows the mean monthly rainfall and rainfalls for each of the monitoring years (station # 312827 – Enfield). Climate station data was used to fill missing data for periods of tipping bucket rain gage malfunction.

2006 was the wettest year of the monitoring period, partly due to Hurricane Ernesto and Tropical Storm Alberto which passed near the site in September and June respectively. The driest year was 2007 when the area experienced widespread drought conditions. The other years were also below normal rainfall, by less than 100 mm; 2009 was the closest to normal falling within 5 mm of the mean normal year. Table 3 shows that a range of high, low, and near normal rainfall years occurred during the monitoring period.

Table 3. Monthly rainfalls for monitoring years at Enfield, NC

Month	Normal (mm)	2005 (mm)	2006 (mm)	2007 (mm)	2008 (mm)	2009 (mm)
January	107	80	56	66	35	48
February	88	77	26	63	109	23
March	107	135	27	69	110	205
April	80	67	82	56	145	32
May	102	148	127	66	100	70
June	93	44	295	114	45	99
July	107	101	142	102	120	53
August	108	49	77	37	107	129
September	116	45	201	40	81	90
October	85	118	125	95	41	30
November	78	99	184	14	113	204
December	83	96	78	133	88	164
Total	1154	1057	1421	854	1093	1149

Groundwater Hydrology

The pasture edge and stream edge water table elevation loggers recorded data for 91% and 94% of the total hours during the monitoring period respectively, capturing a majority of the fluctuations in the water table. Figure 9 shows the water table at the pasture edge and stream edge for Block 1 in 2009. The water table was highest during the winter and early spring, and it usually reached its lowest elevations during the autumn months. Late spring and summer months had an overall decreasing trend in water table elevations except when large rain events briefly raised the water table to elevations similar to those found in winter months. Figure 9 is typical for all monitored years in Block 1 except 2006, which had higher water tables during the summer due to the tropical weather systems mentioned

previously. Plots of water table elevations and rainfall from other years in the monitoring period can be found in Appendix A.

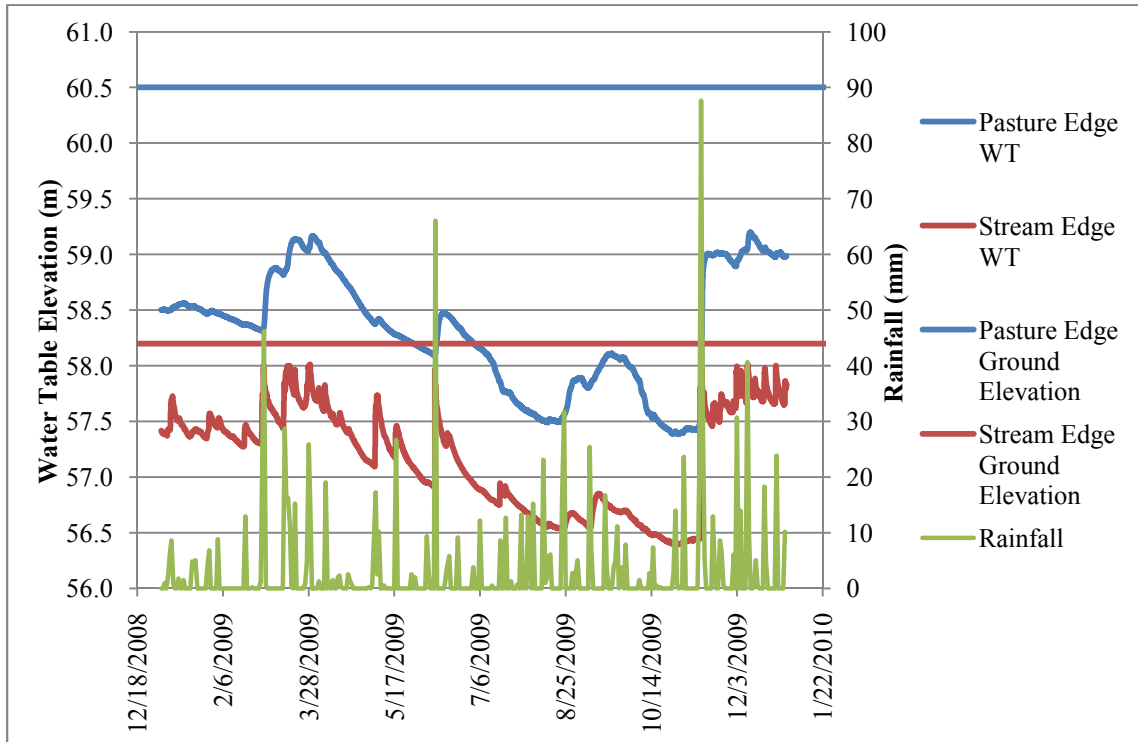


Figure 9. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts for 2009.

Water Table Proximity to the Ground Surface

High water tables and saturated soils are often associated with denitrification because they typically create anaerobic and reduced soil conditions. Wetlands, for example, are identified as prime ecosystems for denitrification. Analyzing the water table depth below the ground surface over time put the relative wetness of different areas of the buffer into perspective. Table 4 shows the percent of each year that the water table was recorded above

a specified depth. At the pasture edge the water table was never within 60 cm of the ground surface. At the stream edge the water table frequently rose above both 60 cm and 30 cm in depth and was noticeably more saturated when compared with the pasture edge. A water table within 60 cm of the ground surface indicates that the water table was within the root zone. The root zone is significant because roots are thought to be a source of carbon to drive denitrification or vegetation could potentially uptake NO_3^- in the groundwater. However, the stream edge did not meet the hydrology requirements for wetlands, which required the water table to be at or above 30 cm below the ground surface in half of the measured years continuously for 5% of the growing season (12 days) (USACE, 1987). The mid-buffer area, along the interface of Zones 1 and 2, may have been able to meet the wetland hydrology requirements. The wetness of this part of the buffer was frequently noted through field observations when compared to the stream edge areas and some facultative wetland vegetation was observed. Unfortunately, no water table measurements were taken in this part of the buffer to confirm. The deep incision of the stream likely created a dry edge along the interface of the stream and buffer as groundwater discharged to the stream.

Table 4. Percent of total year water table was at or above specified depth below the ground surface for Block 1

Year	Pasture Edge			Stream Edge		
	0 cm	30 cm	60 cm	0 cm	30 cm	60 cm
2005	0%	0%	0%	0%	9%	40%
2006	0%	0%	0%	0%	7%	47%
2007	0%	0%	0%	0%	5%	31%
2008	0%	0%	0%	0%	2%	21%
2009	0%	0%	0%	0%	4%	26%
Mean	0%	0%	0%	0%	6%	33%

Flow Direction

Manual water table readings from each monitoring well were inputted into SURFER 7 (Golden Software®, Golden, CO) to determine groundwater flow direction within the buffer. Figure 10a illustrates the groundwater contours for Block 1 when the water table was close to the surface in March 2009. Flow is relatively perpendicular to stream flow during this period. Figure 10b shows a similar map in October of 2008, typically a dry period in the buffer. During this time groundwater flow is still generally perpendicular to stream flow but does turn toward a more parallel direction with stream flow especially directly adjacent to the stream. Only 4 months out of the 18 months that were sampled showed any significant parallel flow in the buffer, August, September, and October, when water tables and groundwater gradients were usually at their lowest. Groundwater flux calculations and groundwater quality analysis all used the assumption of perpendicular flow through the buffer because the amount of each year that groundwater flowed parallel to the direction of stream flow was short.

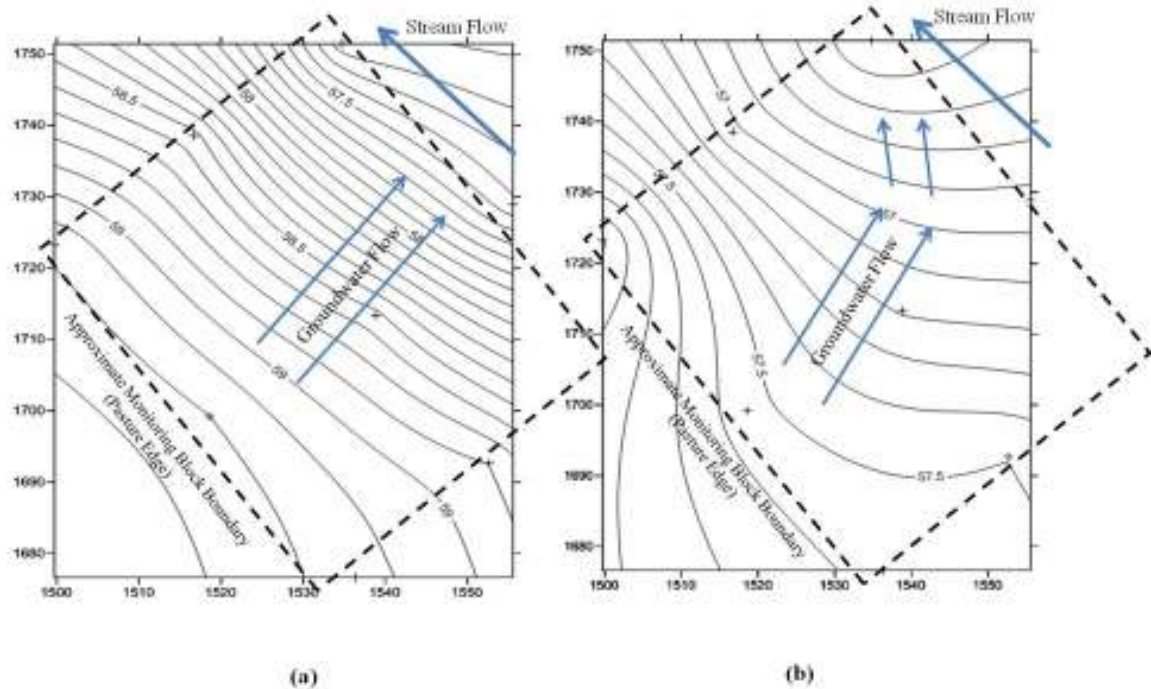


Figure 10. Block 1 groundwater flow directions from (a) March 2009 (wet period) and (b) October 2008 (dry period). Topographic lines represent elevations of the water table in meters. + signs indicate monitoring well locations where groundwater elevation was measured.

Residence Time

Residence time calculations for Block 1 showed that the minimum residence time within the buffer was about 6.4 years. The maximum residence time could not be calculated because of negative gradients. A negative gradient indicates that water was flowing from the stream toward the pasture edge, meaning essentially that the water would never be discharged to the stream if the gradient remained negative. The median and mean residence times were both about 10.7 years. It is important to note that groundwater movement was not at a constant velocity through the buffer. Instead groundwater likely moved more rapidly

during some parts of the year, then slowed down, possibly at times even flowing from the stream into the stream edge of the buffer, and as found in the groundwater direction flowed from the upstream part of the buffer to the downstream for brief periods. These details indicate that the mean and median residence times presented here were likely shorter than the actual residence times of the buffer.

Groundwater Quality – Nitrate (NO₃⁻)

Nitrate-nitrogen concentrations were sampled and assessed in the groundwater to determine if concentrations and loads decreased as the groundwater moved from the pasture edge to the stream edge. Figure 11 is a boxplot of deep (3.0 m depth) and shallow (1.5 m depth) groundwater NO₃-N concentrations in Block 1. A decreasing trend in median concentration was observed from the pasture edge (well position 1) to the mid-buffer (well position 2) and to the stream edge (well position 3) for both deep and shallow groundwater. This indicated that NO₃-N was removed biologically (ie. denitrification or vegetation uptake) or diluted by groundwater mixing.

Groundwater located at the pasture edge had the largest range of concentrations compared to mid-buffer or stream edge groundwater. Shallow pasture edge groundwater ranged from 0.1 mg/L to 114.8 mg/L while the deep pasture edge groundwater concentrations ranged from 0.4 mg/L to 31.4 mg/L. Shallow groundwater at the mid-buffer ranged from 0.0 mg/L to 29.2 mg/L and mid-buffer deep groundwater ranged from 0.1 mg/L to 19.8 mg/L. Finally, groundwater at the stream edge had the smallest range of sampled

values ranging from 0.0 mg/L to 19.2 mg/L for shallow groundwater and from 0.0 mg/L to 7.0 mg/L for deep groundwater. The larger ranges in concentration at the pasture edge were likely because concentrations at the mid-buffer and stream edge were moderated by the buffer, either from biological treatment, by mixing groundwater that occurred in the buffer, or because mid-buffer and stream edge wells did not receive any direct surface runoff from the pasture.

The mean values for pasture edge groundwater was 15.3 mg/L for shallow wells and 10.5 mg/L for deep groundwater. At the mid-buffer mean concentrations were 6.1 mg/L and 7.0 mg/L, while stream edge groundwater means were 0.9 mg/L and 1.2 mg/L for shallow and deep wells respectively. These values corresponded to a percent reduction in concentrations of 94% in shallow groundwater and 89% for deep groundwater through this portion of the buffer.

Statistical analysis showed that differences in NO₃-N between the shallow groundwater at different well positions in the buffer was significant except between the pasture edge and mid-buffer ($p=0.2576$). The same was true for deep groundwater, all differences were statistically significant except between pasture edge and mid-buffer ($p=0.6089$). Clearly overall NO₃-N concentrations decreased between the pasture edge and stream edge during 2005-2010.

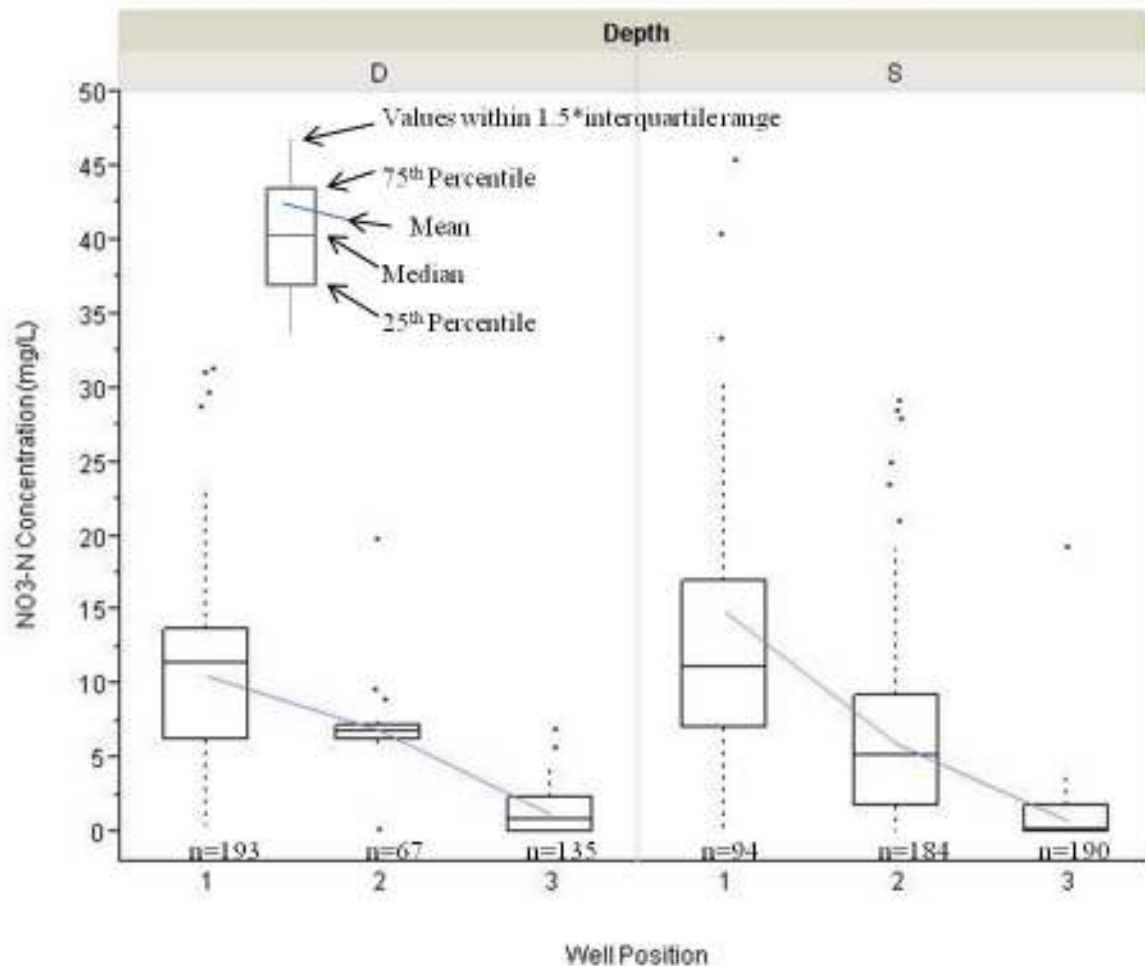


Figure 11. Block 1 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater NO₃-N concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3) from 2005-2010. Lines represent the trend between mean values for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PES-114.8 mg/L, 112.1 mg/L and 51.7 mg/L.

Differences in groundwater concentrations between transects in Block 1 are shown in Figure 12 for shallow groundwater and Figure 13 for deep groundwater. Differences were

most noticeable in the pasture edge shallow groundwater. The transect A pasture edge mean concentration was 21.3 mg/L while transect B and transect C had a pasture edge mean concentrations of 10.7 mg/L and 11.5 mg/L respectively. The large mean concentration at transect A is partly due to two samples taken in January and February of 2006, measuring 114.8 mg/L and 112.1 mg/L respectively. Despite the difference in pasture edge concentrations, transect A and transect B had similar concentrations at the stream edge of about 0.1 mg/L. Transect C had a slightly larger mean concentration at the stream edge of about 2.0 mg/L.

The deep wells had similar mean concentrations at the pasture edge of 9.3 mg/L, 10.1 mg/L and 12.2 mg/L for transects A,B, and C respectively. Note that no deep wells existed at the transect A mid-buffer and stream edge well positions, or the transect B mid-buffer well position due to installation difficulties. Similar to the shallow wells, transect C had a slightly higher concentration at the stream edge, 2.0 mg/L, when compared with transect B that had a concentration of 0.1 mg/L.

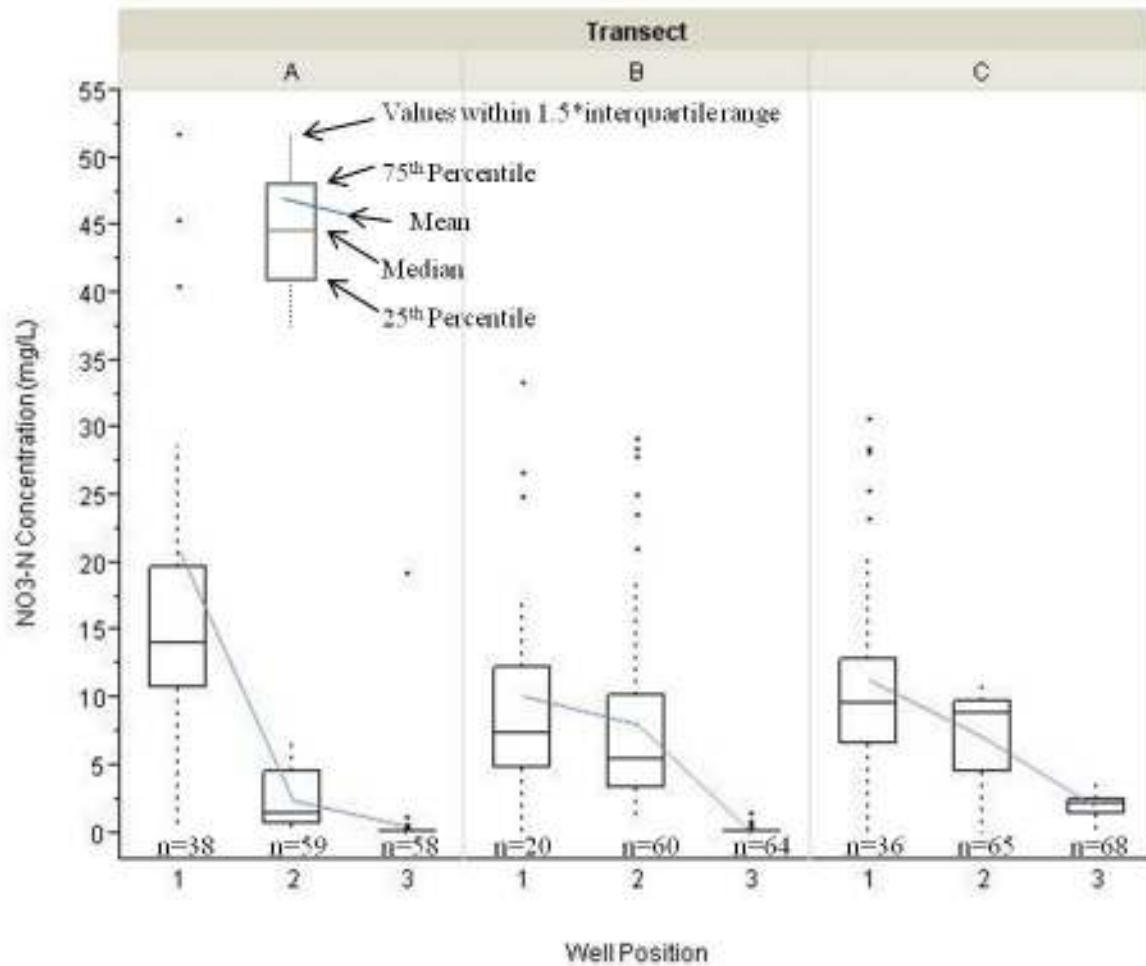


Figure 12. Block 1 shallow (1.5 m depth) groundwater NO₃-N concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PES-114.8 mg/L and 112.1 mg/L

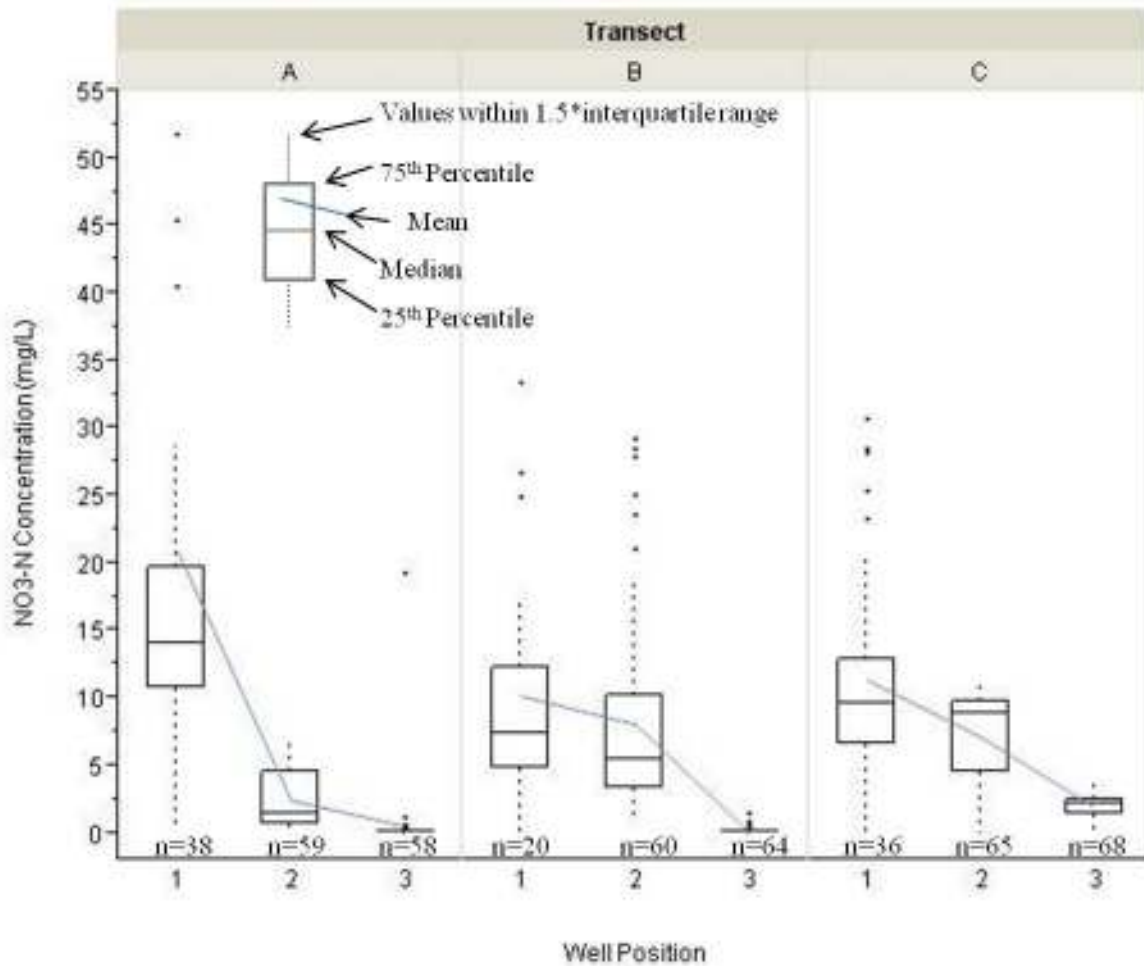


Figure 13. Block 1 deep (3.0 m depth) groundwater NO₃-N concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend between mean values for each well position.

Nitrate-nitrogen concentrations were also visually analyzed for any seasonal trends in incoming concentrations at the pasture edge. All groundwater samples on a single date were averaged for each pasture edge well position. Deep and shallow groundwater NO₃-N concentrations were then graphed by season over the entire monitoring period as shown in

Figure 14. No strong seasonal trend could be identified, however, periods of higher concentrations were generally found in the winter and spring of each year, such as the winter and spring of 2006.

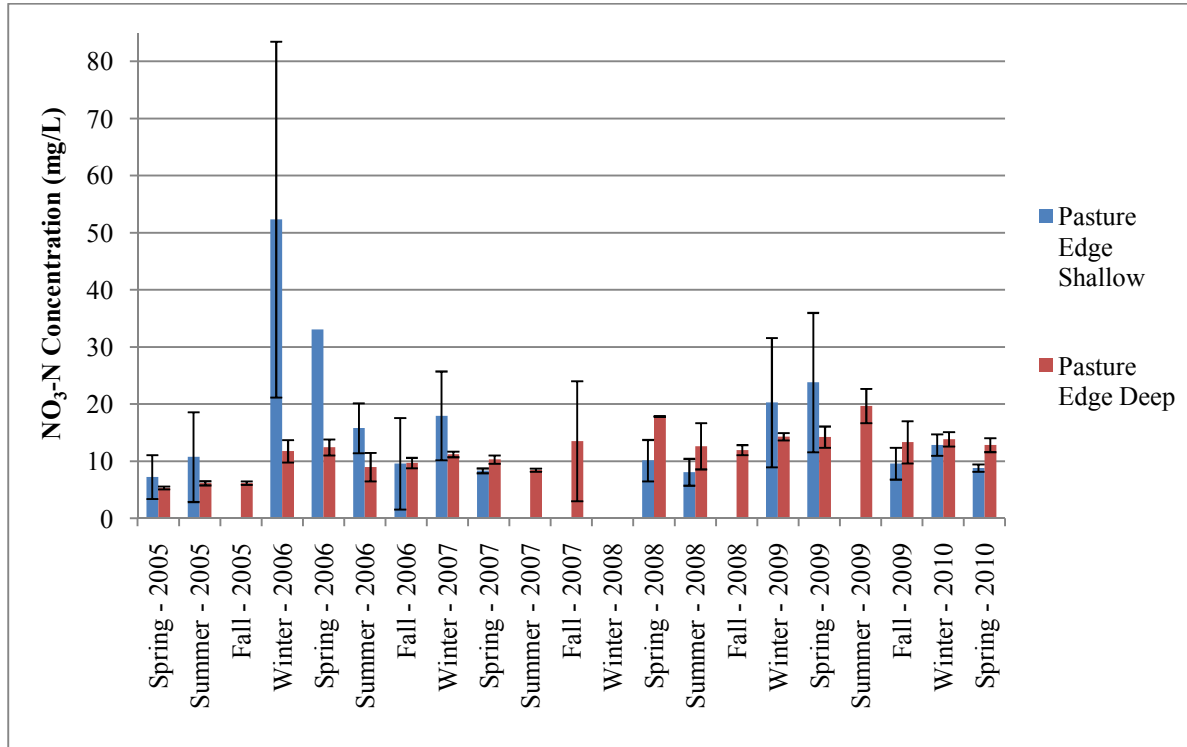


Figure 14. Block 1 mean NO₃-N seasonal concentrations over the monitoring period. Error bars represent standard deviations of individual seasonal mean concentrations.

Nitrate-nitrogen loads were calculated to determine the impacts the buffer has on reducing the mass of NO₃-N being delivered to the stream. Table 5 shows the yearly NO₃-N loads per hectare of contributed area calculated for 3.0 m (10 ft) and 1.5 m (5 ft) depth over the monitoring period. It should be noted that the shallow and deep layers refer to approximately 1.8 m (6 ft) sections of groundwater in the upper aquifer from the top of the water table down to the saprolitic soil layer discussed in the soils section. Because of

observed drops in NO₃-N concentrations, the total combined load of the different depths decreased from pasture edge to stream edge in every monitoring year. Yearly total pasture edge NO₃-N loads ranged from 2.3 to 5.7 kg/ha/yr. A review of relevant literature found these values were on the lower end of ranges reported by Line et al (2000) and Beulac and Reckhow (1982) for pastures. Both of these studies reported NO₃⁻ load export ranges of 6-36 kg/ha/yr and approximately 2-30 kg/ha/yr respectively. Some of this discrepancy could be because these studies measured loads in streams at the outlet of the watershed rather than in groundwater like this study. Calculated stream edge total loads ranged between 0.2 and 0.4 kg/ha/yr. This corresponded to reductions in load between the pasture edge and stream edge wells of 81% to 95%. A mean reduction of load was calculated to be 3 kg/ha or about a 91% reduction in load

The calculated annual load delivered to the buffer was larger in the shallow groundwater for a majority of the monitoring period. This was likely because the composite saturated hydraulic conductivity was twice as high in the shallow layer than in the deep layer (1.6 cm/hr and 0.8 cm/hr respectively), so that a larger volume of water was able to flow through the shallow layers during the monitoring period. Shallow groundwater also received NO₃⁻ inputs directly from the pasture while NO₃⁻ in the deeper layers needed to first diffuse through the shallow groundwater before being transported at that depth.

The largest pasture edge loads were calculated for the years that had the largest concentrations of NO₃-N, 2006 and 2009, especially in the winter and spring of these years

as shown in Figure 14. The other years in the monitoring period had similar concentrations and similar loads at the pasture edge. Mid-buffer and stream edge loads remained nearly constant throughout the monitoring period, indicating very little effect of the different years.

Table 5. Block 1 NO₃-N loads for shallow (1.5 m depth) and deep (3.0 m depth) groundwater depths.

Year	Pasture Edge			Mid-Buffer			Stream Edge		
	Shallow	Deep	Total	Shallow	Deep	Total	Shallow	Deep	Total
	<i>(loads in kg/ha)</i>								
2005	1.6	0.7	2.3	1.2	0.7	1.9	0.3	0.1	0.4
2006	4.6	1.1	5.7	1.9	0.7	2.5	0.2	0.1	0.3
2007	1.3	1.0	2.3	1.7	0.6	2.3	0.2	0.1	0.3
2008	1.2	1.4	2.7	0.7	1.0	1.6	0.1	0.1	0.2
2009	2.2	1.7	3.9	1.5	0.9	2.4	0.2	0.1	0.3
2010	1.9	0.6	2.4	0.9	0.3	1.2	0.0	0.0	0.1
Totals	12.9	6.4	19.3	7.8	4.2	12.0	1.1	0.5	1.6

Redox

Redox potentials were measured to determine if the anaerobic conditions associated with the denitrification process occurred in the buffer and could support that observed reductions in NO₃-N concentrations were due to denitrification. Kralova et. al. (1992) and Bailey and Beauchamp (1973) found that denitrification was a major process at redox potentials below +200 mV. Bailey and Beauchamp also found that denitrification could occur at higher potentials, likely up to 400 mV, but that oxygen was simultaneously being reduced at potentials greater than +200 mV. Table 6 shows the percent of each year that each probe was below the water table as well as the percent of sampling events each year that the

mean redox potential was below +200 mV, when O₂ was likely depleted and NO₃⁻ was a primary electron acceptor, and below +350 mV, where both O₂ and NO₃⁻ were likely being utilized as electron acceptors. It is important to note that the reported redox potentials are just small points meant to estimate soil redox potentials for the entire buffer. Other locations in the buffer may have had either more positive or more negative potentials depending on localized conditions.

Table 6. Percent of each year Block 1 redox probes at the shallow (1.5 m depth) and deep (3.0 m depth) were below the water table and percent of sampling events each year that mean redox potentials were less than 200 mV or less than 350 mV.

Probe Location		2006 (n=6)	2007 (n=9)	2008 (n=7)	2009 (n=12)
Pasture Edge	% saturated*	19%	14%	16%	25%
Shallow (1.5 m depth)	<200mV	83%	100%	71%	25%
	<350mV	100%	100%	100%	100%
Pasture Edge	% saturated*	100%	68%	86%	85%
Deep (3.0 m depth)	<200mV	100%	89%	71%	58%
	<350mV	100%	100%	100%	92%
Mid-Buffer	% saturated*	100%	100%	74%	75%
Shallow (1.5 m depth)	<200mV	100%	67%	0%	0%
	<350mV	100%	100%	100%	92%
Mid-Buffer	% saturated*	100%	100%	100%	100%
Deep (3.0 m depth)	<200mV	0%	0%	0%	0%
	<350mV	0%	56%	71%	58%
Stream Edge	% saturated*	100%	80%	83%	84%
Shallow (1.5 m depth)	<200mV	17%	67%	14%	58%
	<350mV	100%	100%	100%	100%
Stream Edge	% saturated*	100%	100%	100%	100%
Deep (3.0 m depth)	<200mV	100%	100%	100%	58%
	<350mV	100%	100%	100%	100%

*Note: % saturated represents percentage of days soil surrounding the redox probe was saturated

Figure 15 shows the deep and shallow pasture edge redox measurements in 2009 and the water table elevations measured using the pasture edge water table logger. The pasture edge shallow redox probes were placed in the soil at an elevation of about 58.8 m (193 ft). Table 6 shows that, for the year 2009, the shallow probes were only below the water table about 91 days (25% of the year). While below the elevation of the water table they showed small decreasing trends in redox potential as dissolved oxygen was likely being depleted

from the water and microbes utilized other electron acceptors, namely NO_3^- , to generate energy. When the water table fell below the shallow probes the redox potential tended to be more positive. The shallow redox potentials were typically at lower potentials in the winter and gradually increased to more positive values through the year, usually until the month of November when the water table was generally at its lowest point below the ground surface. By December the potentials decreased again, except in 2008 when they remained at about the same values as those measured previously in November. This was generally true for all years monitored. Table 6 shows that the shallow pasture edge probe was below the +200 mV threshold for only about 25% of the sampling events in 2009 but was below the +350 mV threshold, where some denitrification may be occurring, for all of the sampling events.

Block 1 pasture edge deep redox probes were installed at an elevation of about 57.6 m (189 ft) and were below the water table for a majority of the year in 2009 as shown in Figure 15. For that year, the probes were only above the measured water table for about 54 days (15% of the year) in late August and early September as well as in October and November. Table 6 shows that the probes were inundated for a majority of the time in each year and mean redox potentials were below the +200 mV threshold for a majority of the sampling events. This indicated that the potential for denitrification at this location and depth was great. Throughout the monitoring years when the deep redox probes had been below the water table for the longest amount of time, usually sometime in late October or early November, the deep redox potentials were measured at the lowest or most negative potential for the year. However, the potential values increased considerably when the water table was

much higher during the wetter parts of the year in winter and spring. The trend suggested that either oxygen levels were lower in the groundwater during the summer and autumn months or microbial activity was higher. This was characteristic of all years monitored.

Over the course of the entire monitoring period, pasture edge shallow redox probes were below the +200 mV threshold for denitrification about 61% of the sampling period while pasture edge deep redox probes were below the threshold for about 71%. Both of the depths were below the +350 mV threshold for between 97% and 100% of the sampling period. This seems to indicate that in-situ redox conditions at the pasture edge were likely favorable for some denitrification to occur for the majority of each year.

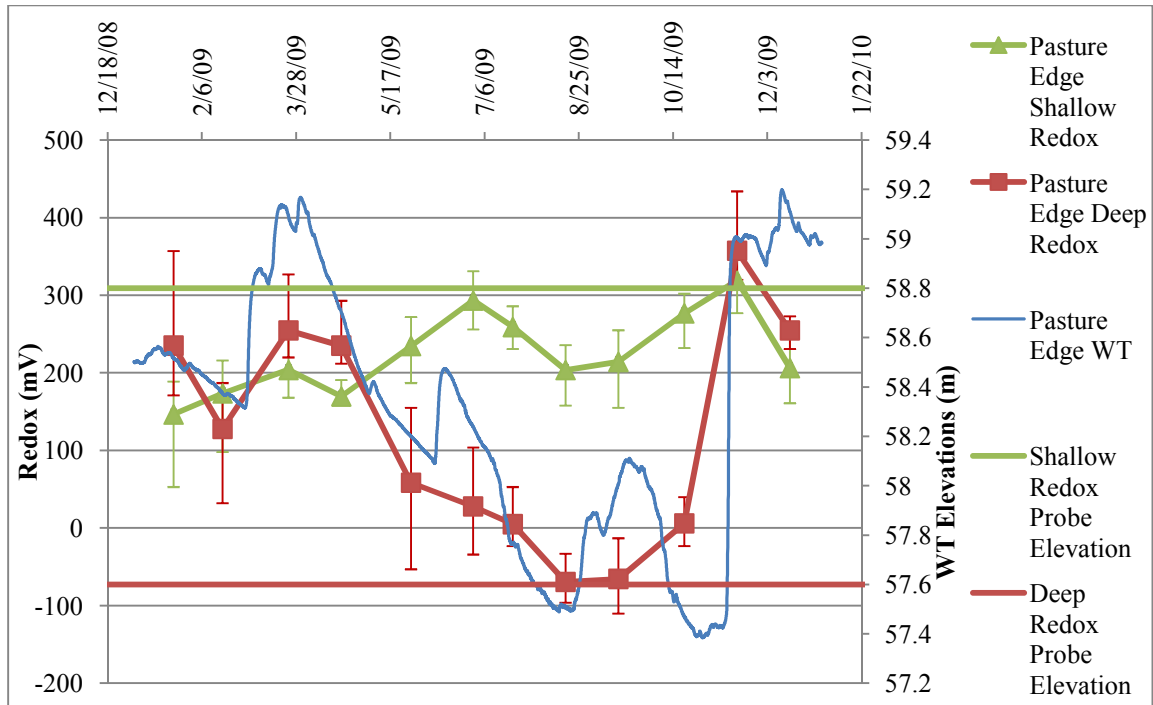


Figure 15. Mean pasture edge redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Figure 16 shows the redox potentials measured in stream edge soils and the stream edge water table elevations. The stream edge redox displayed trends very similar to those found at the pasture edge. Shallow 1.5 m (5 ft) depth potentials were more positive than the deep depth and tended to stay at relatively the same value or increase in value only slightly through the year. Deep 3.0 m (10 ft) depth redox potentials at the stream edge were at the lowest potential when they had been below the water table for the longest period of time, again typically during the autumn months. Table 6 shows that shallow probe mean redox values were above the +200 mV threshold for only a few of the events in 2006 and 2008, but

for a majority in 2007 and 2009. Mean potentials for the shallow stream edge probe were never greater than +350 mV for the entire monitoring period; these probes were also below the elevation of the water table for a majority of each year. Deep probes at the stream edge were below the elevation of the water table for a majority of each year and mean redox values were below the +200 mV threshold in every monitoring year except 2009 but were never above +350 mV during this year. Throughout the entire monitoring period shallow probes were below the +200 mV and +350 mV thresholds for 24% and 89% of the period respectively. This indicated that there was potential for denitrification to occur but that oxygen was likely also being utilized by microbes for significant portions of the monitoring period. Deep probes at the stream edge were below the +250 mV and +350 mV thresholds for 82% and 100% respectively. This indicated that the potential for denitrification was strong throughout the monitoring period.

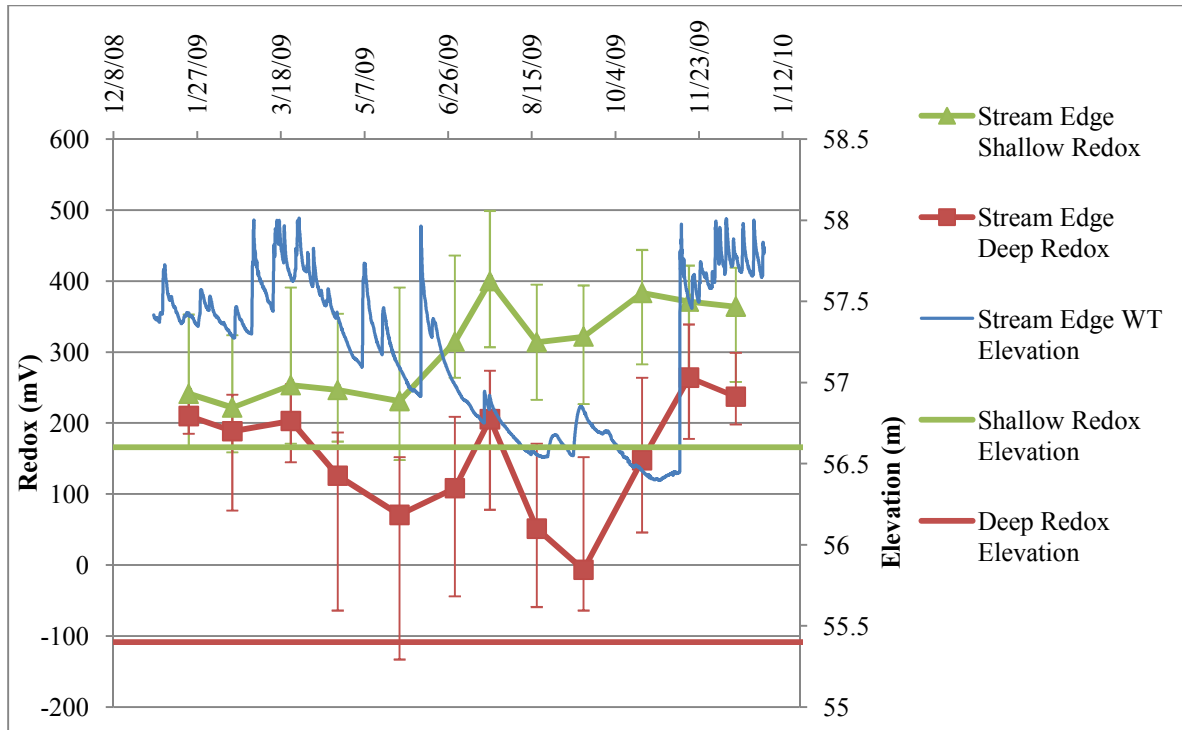


Figure 16. Mean stream edge redox potentials and and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Figure 17 shows the mid-buffer shallow and deep measured redox potentials for 2009. An estimate of the water table was used in the figure because no water table loggers were installed at the mid-buffer position. The estimate was obtained by adding the difference in ground elevation between the mid-buffer and stream edge well positions (about 0.5 m (1.6 ft)) to the stream edge water table elevations that were logged in the monitoring block. This was likely a conservative estimate of the actual water table at the mid-buffer because the incised stream lowered the water table near the stream edge. Mid-buffer shallow probes were below the water table for a majority of each year, as water tables were generally very

high in this part of the buffer. Table 6 shows the mid-buffer shallow values never fell below the +200 mV threshold in 2009 or 2008 but did in 2006 and 2007, however, the shallow potentials were below the +350 mV threshold for every sampling event except one in 2009.

Deep redox potentials at the mid-buffer did not display any trends that were similar to the deep pasture edge or deep stream edge potentials. The mid-buffer deep values were much more positive, more positive than the mid-buffer shallow probes, and never fell below the +200 mV threshold during the monitoring period. This probe continually had the fewest measurements below the +350 mV threshold as well with values ranging from 0% to 71% of the samplings. This was unexpected as the water table inundated the deep redox probes for the entire monitoring period in this part of the buffer. The very positive mean redox potential values in the deep cluster did not seem to be due to a equipment problems as several of the probes had unexpectedly high readings throughout the monitoring period. One possible explanation is that oxygen laden rainfall or surface runoff was able to infiltrate around the bentonite cap of the redox probe cluster and percolate to the probe tips. This possible extra infusion of oxygen could have been enough to give the area around the probes more positive readings. Throughout the entire monitoring period shallow probes were below the +200 mV and +350 mV thresholds for 34% and 95% respectively while deep probes were below the thresholds for 0% and 47% respectively.

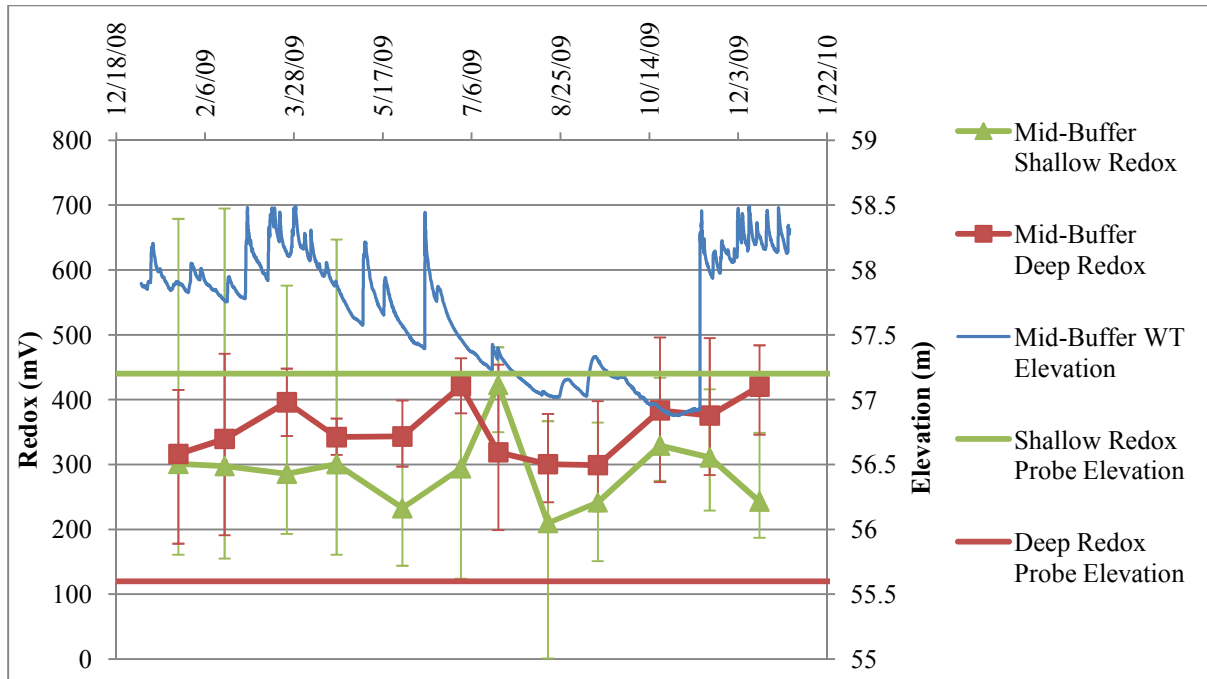


Figure 17. Mean mid-buffer redox potentials and and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Groundwater Quality – Dissolved Organic Carbon (DOC)

To assess soil carbon availability for denitrification, dissolved organic carbon (DOC) was sampled at the site from August 2008 to February 2010 on a bi-monthly basis. Figure 18 is a boxplot of Block 1 DOC concentrations and shows that median groundwater concentrations were similar throughout the buffer, ranging from 1.8 mg/L to 4.8 mg/L. Mean groundwater concentrations were also similar ranging from 4.1 mg/L to 6.9 mg/L. No statistically significant differences in DOC concentrations were found between any of the well positions (values ranged from $p = 0.2893$ to $p = 0.7501$) except between the shallow mid-buffer well position (Well Position 2) and the shallow stream edge well position (Well

Position 3). Seasonal changes in DOC are shown in Figure 19. A seasonal trend in concentrations could not be detected because DOC was only sampled for 18 months. The figure does show that concentrations were highest during the summer of 2008 much lower during the following time periods and then slightly elevated again during the winter of 2010. The figure also shows that that DOC was fairly evenly distributed in groundwater between the different areas of the buffer.

Mean DOC concentrations in Block 1 were on the lower side of the range that denitrification has been shown to occur by other researchers. Obenhuber and Lowrance (1991) found that a small amount of denitrification could occur with DOC concentrations of about 4 mg/L in laboratory microcosms and that the rate drastically increased when DOC concentration were increased to 10 mg/L. Similarly, Starr and Gillham (1993) found that significant denitrification occurred in a sandy aquifer with DOC concentrations from about 8 mg/L to 10 mg/L while almost no denitrification could be identified in an aquifer with 2 mg/L to 3 mg/L concentrations of DOC. While a majority of Block 1 DOC concentrations were on the lower side of the denitrification range, samples at all well positions were frequently measured with much higher concentrations, in some cases above 15 mg/L. This seemed to suggest that DOC concentrations in the buffer were sufficient to support some denitrification assuming the other criteria for denitrification were met.

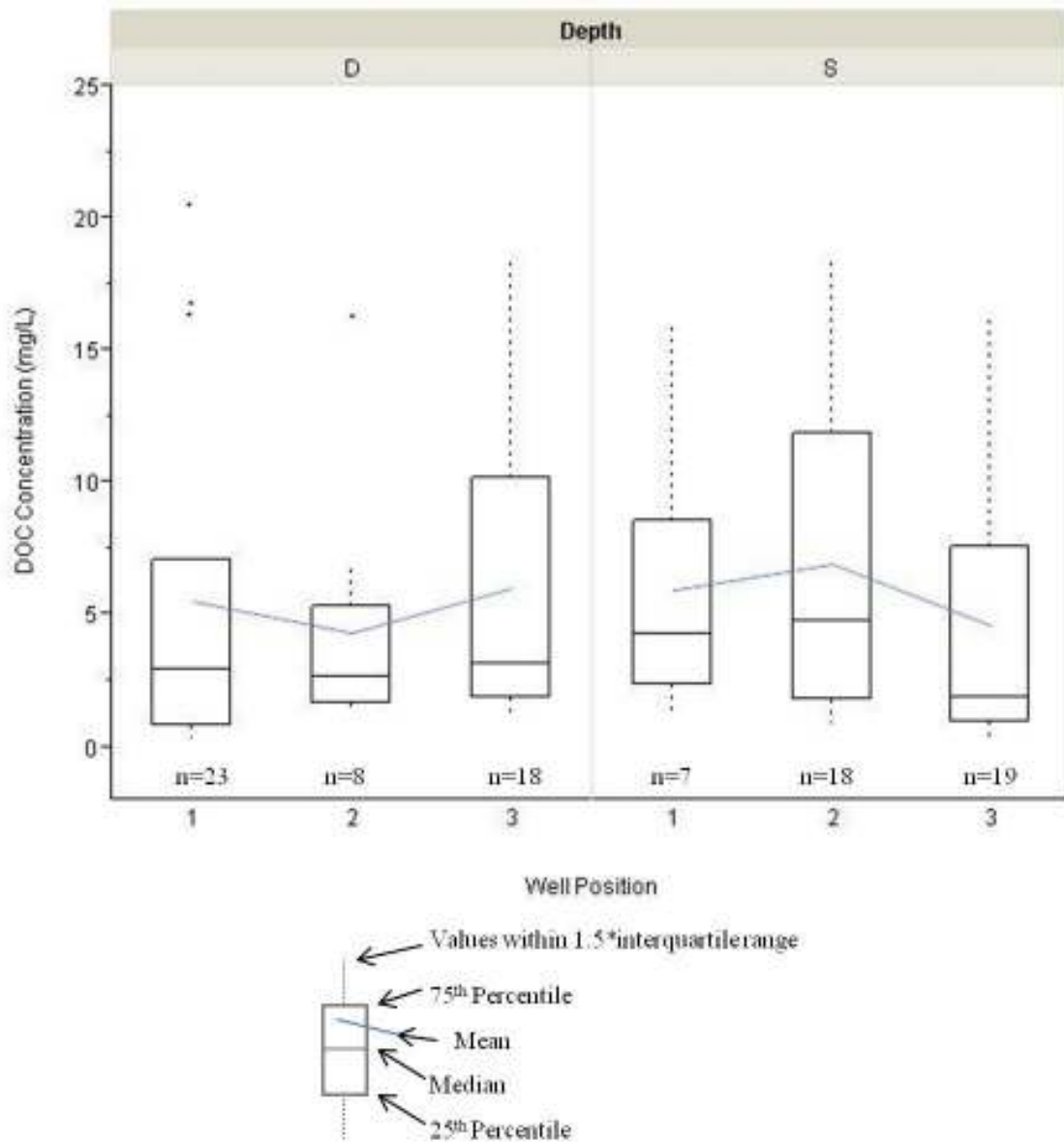


Figure 18. Block 1 DOC samples in deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position.

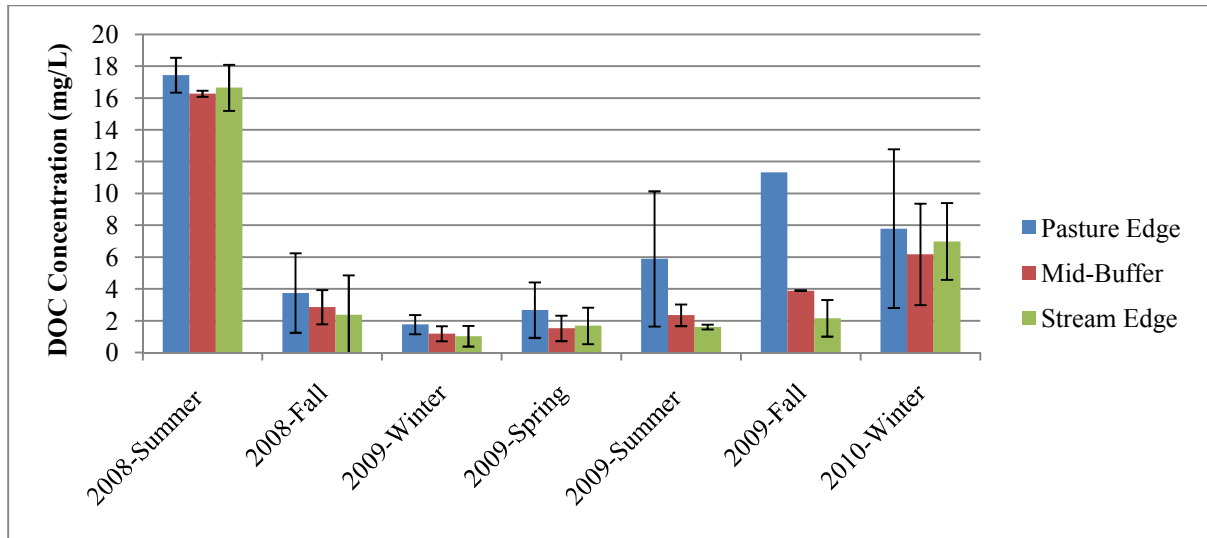


Figure 19. Block 1 mean seasonal DOC concentrations. Error bars represent standard deviations for each value.

Redox potentials and groundwater DOC concentrations in Block 2 both indicated that the conditions required for denitrification to occur were present in the monitoring period. Reductions in $\text{NO}_3\text{-N}$ concentrations between the pasture edge and stream edge groundwater could potentially be attributed to denitrification.

Groundwater Quality – Nitrate/Chloride Ratios ($\text{NO}_3\text{-N}/\text{Cl}^-$)

Cl^- concentrations were used to normalize $\text{NO}_3\text{-N}$ concentrations to determine if $\text{NO}_3\text{-N}$ was actually being removed from the buffer, via vegetation uptake or denitrification, or if concentrations were being diluted by $\text{NO}_3\text{-N}$ poor groundwater mixing with the surficial aquifer. The source of Cl^- in groundwater that was entering the buffer was the same as the source of $\text{NO}_3\text{-N}$, poultry litter that was broadcast on the upland pasture as fertilizer. $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios that decrease from the pasture edge to the stream edge are usually associated with $\text{NO}_3\text{-N}$ removal in the buffer, assuming a nearly constant Cl^- concentration. Ratios that do

not change from the pasture edge to the stream edge are indicative of dilution by a $\text{NO}_3\text{-N}$ and Cl^- poor groundwater source and not $\text{NO}_3\text{-N}$ removal. Ratios that increase across the buffer might indicate that either $\text{NO}_3\text{-N}$ was increasing across the buffer while Cl^- was stable or $\text{NO}_3\text{-N}$ concentrations were stable while Cl^- concentrations were decreasing. Both of these scenarios would require a source of $\text{NO}_3\text{-N}$ originating inside the buffer.

Overall mean $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios decreased from pasture edge to stream edge as shown in Figure 20. Analysis of individual transects also show that ratios decreased between the pasture edge and stream edge as shown in Figures 21 and Figure 22, for shallow and deep groundwater respectively. There was no difference in ratios between the pasture edge (Well Position 1) and mid-buffer groundwater (Well Position 2) in either the shallow (1.5 m) or deep (3.0 m) groundwater ($p = 0.0943$ and $p = 0.5605$ respectively). All other differences in ratios between well positions were found to be significant. This seemed to indicate that the most important decrease in Block 1 $\text{NO}_3\text{-N}$ concentrations occurred between the mid-buffer and stream edge groundwater. The percent reduction in mean $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios from the pasture edge to the stream edge was about 92% for shallow groundwater and 79% for deep groundwater. At the shallow (1.5 m) groundwater depth this reduction was similar to the percent reductions calculated for $\text{NO}_3\text{-N}$ concentrations. The deep well reduction was slightly lower than the percent reductions calculated for deep groundwater mean $\text{NO}_3\text{-N}$ concentrations.

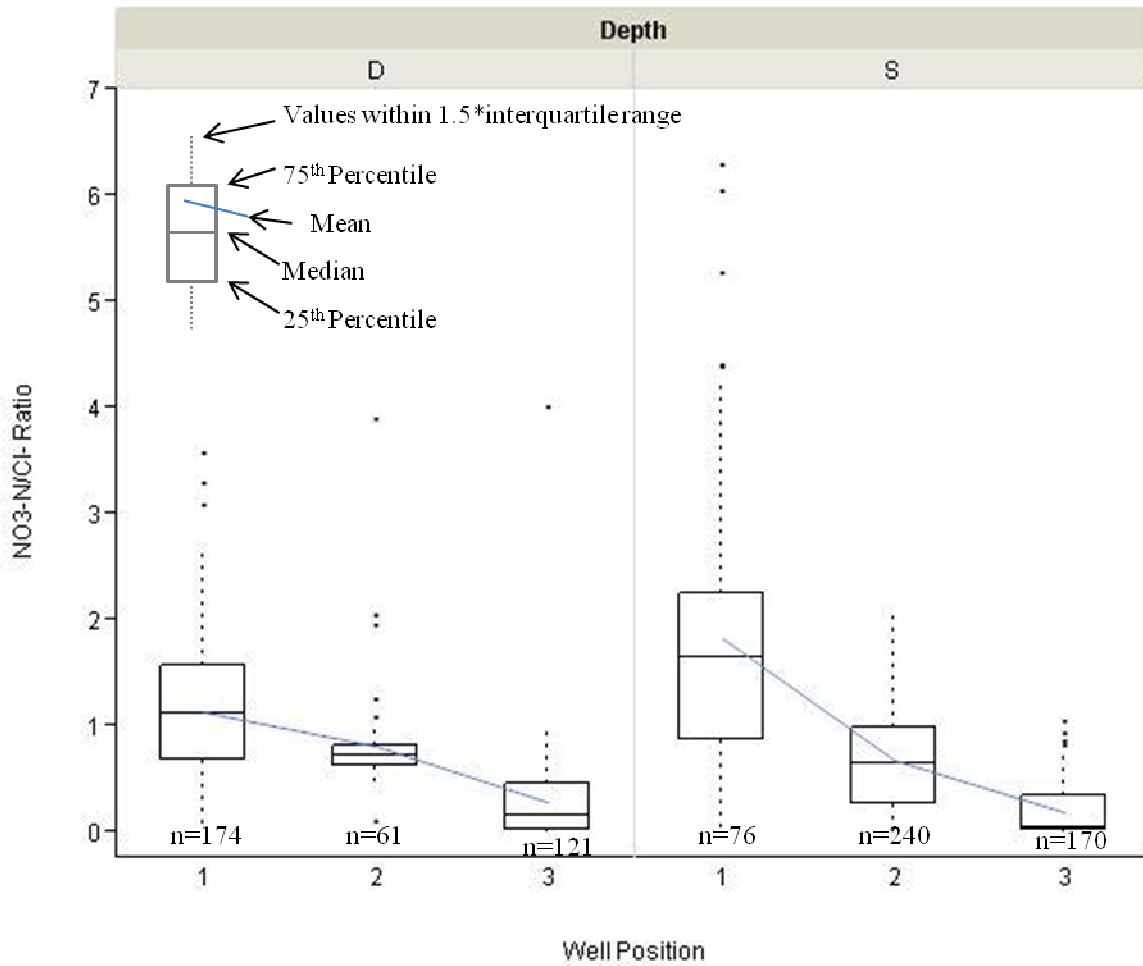


Figure 20. Block 1 shallow (1.5 m depth) and deep (3.0 m depth) groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend between means at each well position.

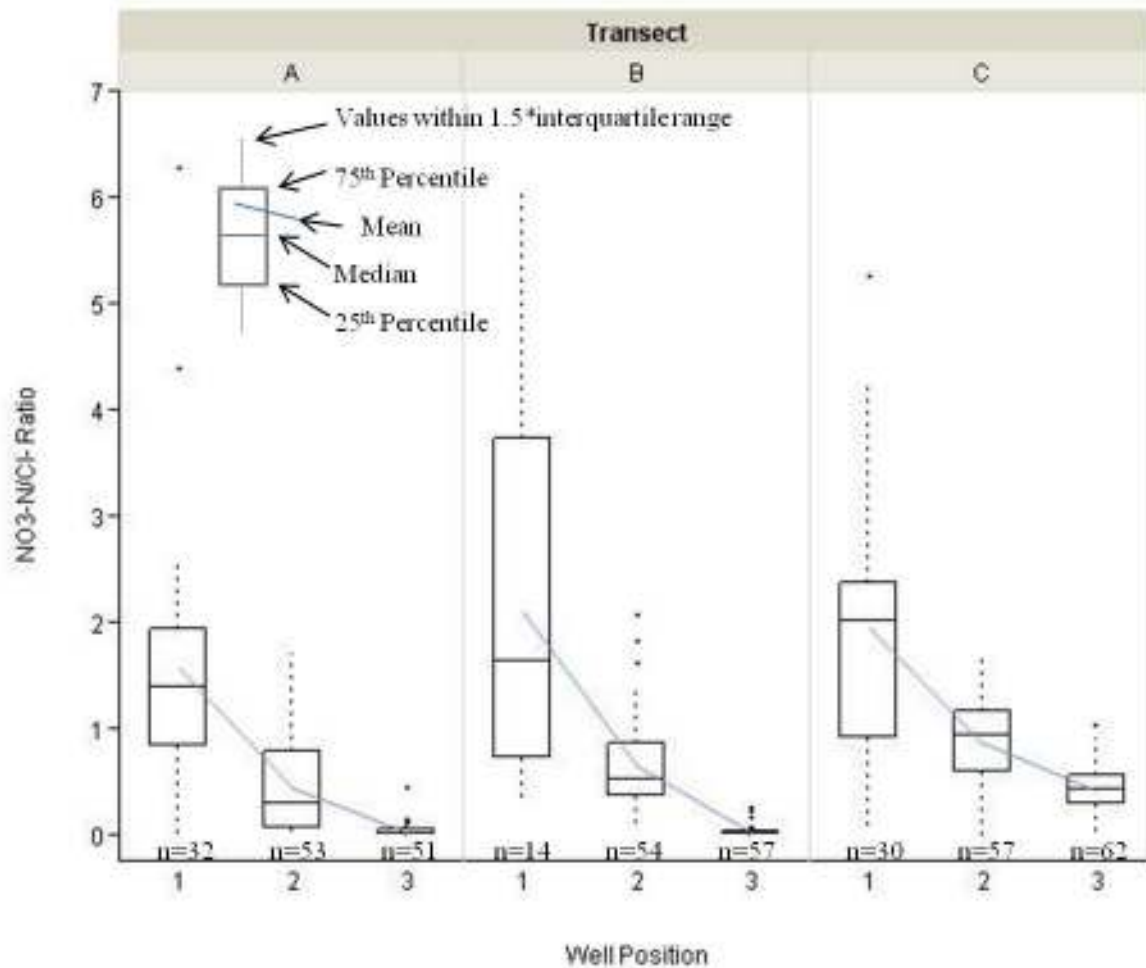


Figure 21. Block 1 shallow (1.5 m depth) groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend between means at each well position.

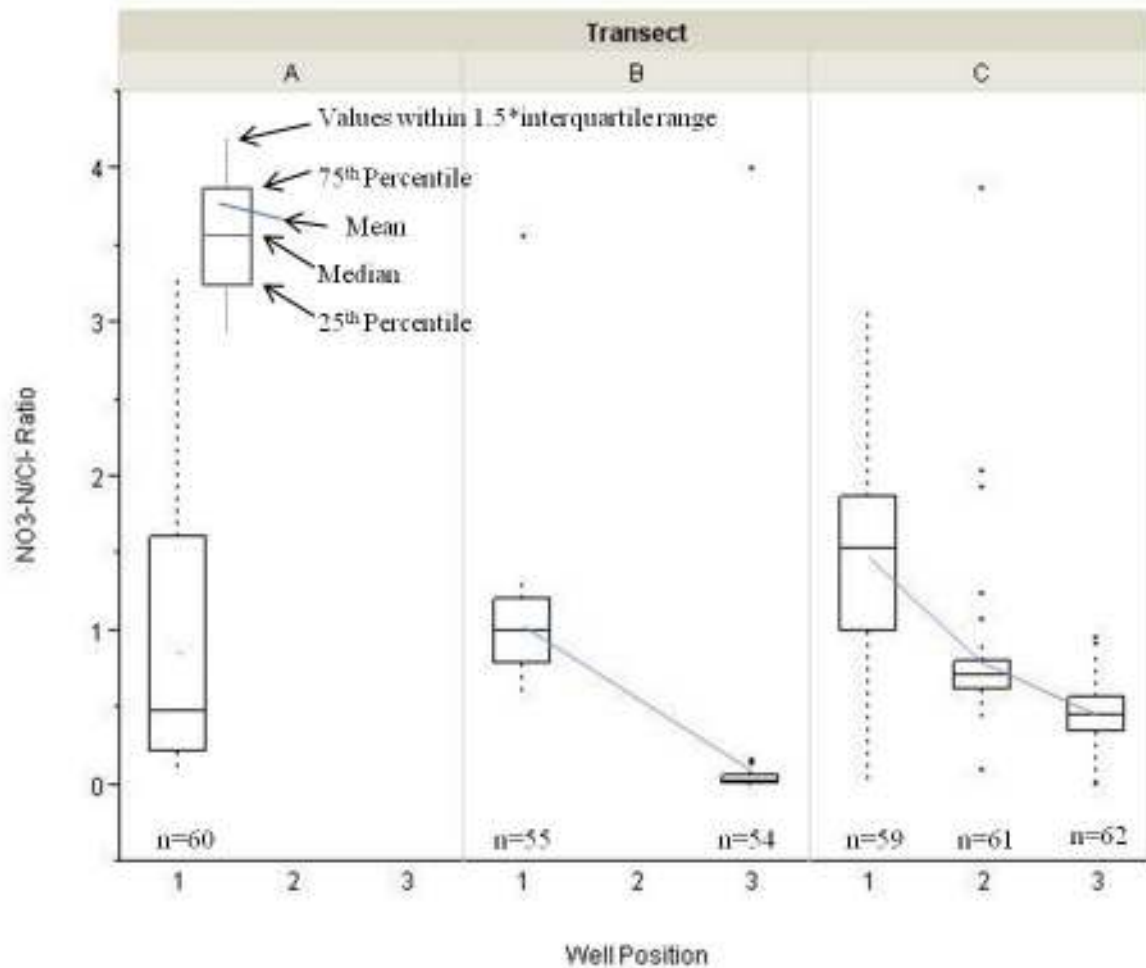


Figure 22. Block 1 deep (3.0 m) groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trends between means for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 5.4.

Groundwater Quality – Chloride (Cl⁻)

NO₃-N/Cl⁻ ratios alone would have indicated that very little dilution due to groundwater mixing was occurring if Cl⁻ concentrations had been constant among all well positions. However, this was not the case in Block 1. Figure 23 is a boxplot of shallow and deep Cl⁻ concentrations in Block 1 groundwater at different well positions. In both shallow (1.5 m depth) and deep (3.0 m depth) groundwater, statistically significant differences in Cl⁻ concentrations were found between pasture edge groundwater and stream edge groundwater and between mid-buffer groundwater and stream edge groundwater. No significant difference was found between the pasture edge well position and the mid-buffer well position for both the shallow and deep depths ($p = 0.3396$ and $p = 0.9710$ respectively). The percent reduction in mean concentrations of Cl⁻ between the pasture edge and the stream edge was calculated to be 56% for shallow groundwater and 70% for deep groundwater. This indicated that dilution from groundwater mixing had the potential to be a major factor in the reduction of NO₃-N concentrations in Block 1, especially between the mid-buffer and stream edge well positions, where the most significant decreases in NO₃-N concentrations also occurred.

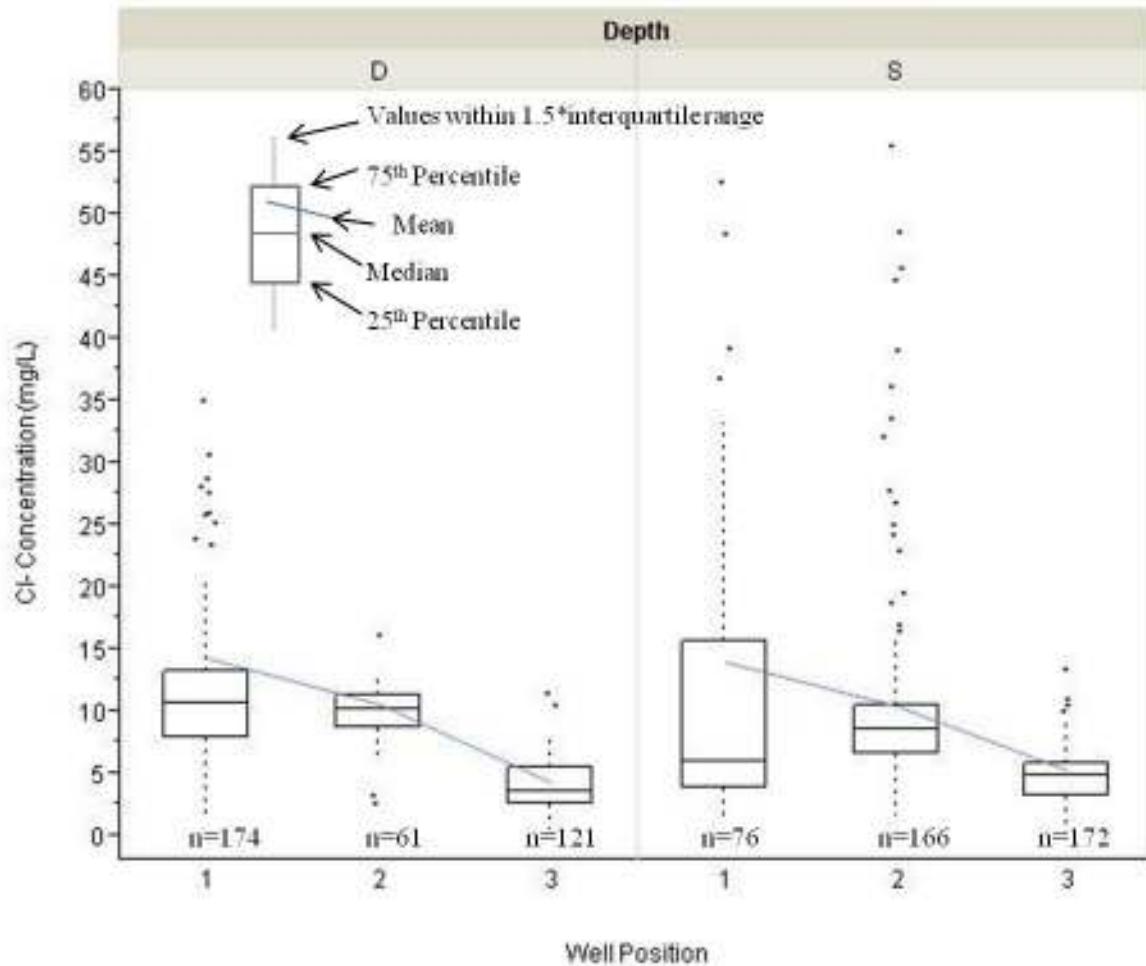


Figure 23. Block 1 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater Cl concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 460.0 mg/L, 86.7 mg/L, MBD - 73.6 mg/L, SED - 61.6 mg/L, PES - 126.0 mg/L, 108.0 mg/L, 76.5 mg/L, SES - 98.0 mg/L.

Transects in Block 1 were examined individually to determine if dilution effects could be further pinpointed to certain areas within the monitoring block. Figure 24 shows the

individual transects in Block 1 for shallow (1.5 m depth) groundwater. Transect A clearly displays the same trend of lowered Cl^- concentrations in stream edge groundwater that was observed in the overall means. Pasture edge and stream edge concentrations were lowest and nearly equal in transects B and C, and highest in the mid-buffer groundwater.

Figure 25 shows the individual transects in Block 1 for deep wells. The decrease in Cl^- concentrations from the pasture edge groundwater to the stream edge groundwater was found in both transect B and C. Clearly the overall trend of smaller concentrations of Cl^- at the stream edge that was found in Figure 23 was also true when deep transects are examined individually.

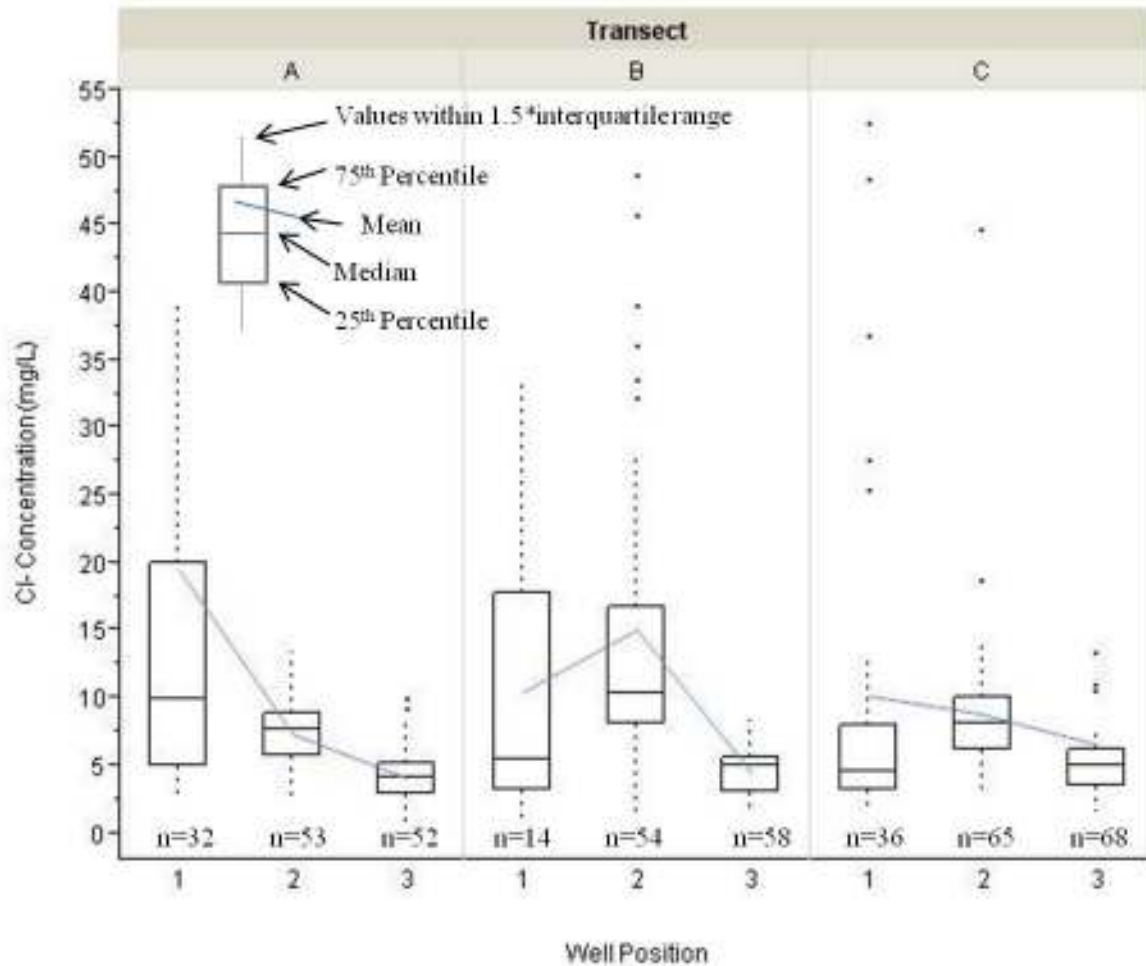


Figure 24. Block 1 shallow (1.5 m depth) groundwater Cl concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PES - 76.5 mg/L, 108.0 mg/L, 126.0 mg/L, MBS - 55.4 mg/L, SES - 98.0 mg/L

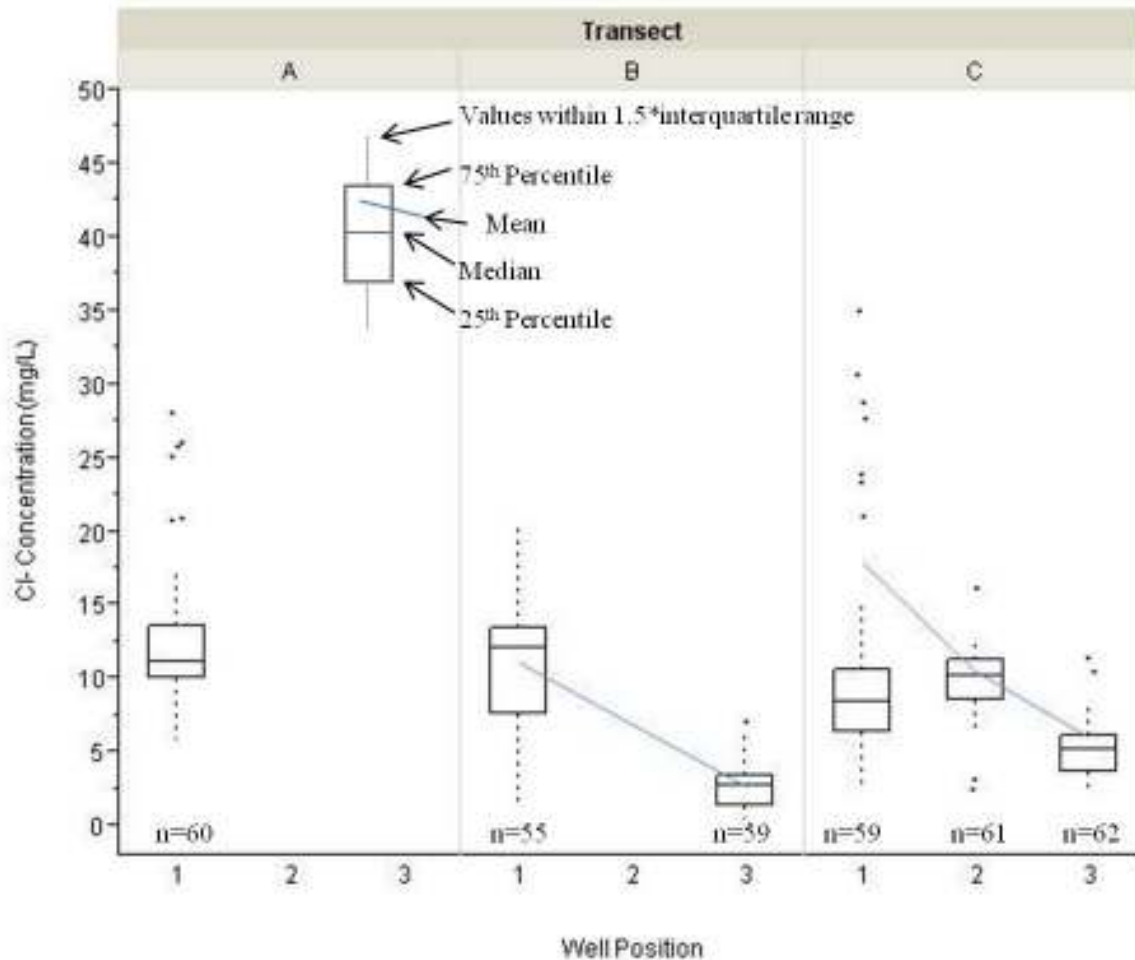


Figure 25. Block 1 deep (3.0 m depth) groundwater Cl⁻ concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 86.7 mg/L, 460.0 mg/L, MBD - 73.6 mg/L, SED - 61.6 mg/L

While decreasing NO₃-N/Cl⁻ ratios initially indicated that NO₃⁻ removal occurred, decreasing Cl⁻ concentrations indicated that dilution also occurred. More investigation was needed so that a better conclusion could be drawn from the data. The mean of groundwater

NO₃-N and Cl⁻ concentrations for all pasture edge and stream edge 1.5 m (5 ft) and 3.0 m (10 ft) depth samples were calculated for each sampling date. The means were then plotted throughout the entire monitoring period as shown in Figure 26 for the shallow 1.5 m (5 ft) groundwater depth and Figure 26 for the deep 3.0 m (10 ft) groundwater depth.

Pasture edge concentrations for three sampling dates, 1/12/2006, 2/9/2006, and 3/9/2006 at the 1.5 m (5 ft) depth, were removed for this analysis due to the high variability in both NO₃-N and Cl⁻ values and for better scaling in Figure 25. Nitrate-nitrogen concentrations ranged from 20.7 mg/L to 114.8 mg/L and Cl⁻ concentrations ranged from 25.3 mg/L to 126.0 mg/L over this small time period. Figure 26 shows that both NO₃-N and Cl⁻ concentrations decreased between the pasture edge shallow groundwater and the stream edge shallow groundwater for a majority of the monitoring period. All of the 33 paired samples from the 1.5 m depth decrease in NO₃-N concentration between the pasture edge and stream edge. A majority of the paired samples decreased substantially, 29 of the 33 samples decreased by more than 5 mg/L and 19 of the 33 samples decreased by more than 10 mg/L. The mean reduction between samples from the pasture edge groundwater and samples from the stream edge groundwater was 88% and the median reduction was 92%. The largest mean reduction was 99% and occurred on 6/8/2006 while the smallest mean reduction was 46% occurring on 6/29/2005.

The difference in Cl⁻ concentrations was not as great, only 22 of the 33 samples decreased in Cl⁻ concentration between the pasture edge groundwater and the stream edge

groundwater. Only 14 of the 33 samples decreased by more than 5 mg/L and only 7 of the 33 paired samples decreased by more than 10 mg/L. The mean reduction between Cl^- concentrations in pasture edge groundwater and concentration in stream edge groundwater was 22% and the median reduction was 36%. The largest reduction was 88% on 11/21/2006 while on 4/6/2005 a 112% increase in Cl^- concentrations was recorded.

Overall Cl^- concentrations decreased in Block 1 shallow groundwater indicating that dilution by groundwater mixing with a Cl^- and $\text{NO}_3\text{-N}$ poor groundwater source was a major process in this monitoring block at the shallow 1.5 m (5ft) depth. Mean concentrations in the groundwater at 5.9 m (19.5 ft) below the ground surface at the stream edge were 2.5 mg/L and 5.4 mg/L for $\text{NO}_3\text{-N}$ and Cl^- respectively and may have been a major source of dilution. Different concentrations of $\text{NO}_3\text{-N}$ and Cl^- in the dilution source could have caused different rates of reductions in the concentrations in the surficial aquifer. However for this analysis dilution was assumed to have the same effect on both $\text{NO}_3\text{-N}$ and Cl^- concentrations in the upper aquifer where the shallow (1.5 m (5 ft) depth) and deep (3.0 m (10 ft) depth) groundwater was located. The greater change in $\text{NO}_3\text{-N}$ concentrations between the pasture edge groundwater and stream edge groundwater when compared to the change in Cl^- concentrations indicated that biological removal in excess of dilution occurred in the block. By subtracting the percent change in Cl^- concentrations from the percent change in $\text{NO}_3\text{-N}$ concentrations the role of biological removal in the buffer could be estimated as shown in Equation 10:

$$\Delta NO_3 - N\% - \Delta Cl^- \% = \Delta NO_3 - N\% \text{ due to biological removal} \quad [10]$$

This analysis was similar to one performed by Schoonover and Williard (2003). Table 19 in Appendix D shows the values that were calculated for each sampling date in the monitoring period. It should be noted that these estimations of biological removal represent the maximum removal that could be expected in the monitoring block, actual removals may have been lower.

The mean difference between the percent reduction in NO₃-N concentrations and the percent reduction in Cl⁻ concentrations between the pasture edge groundwater and the stream edge groundwater was 53% while the median difference was 47%. This meant that, on average, NO₃-N concentrations decreased by a larger rate than Cl⁻ concentrations decreased between the pasture edge groundwater and the stream edge groundwater at the 1.5 m (5 ft) depth. A maximum difference in reductions was recorded on 2/8/2010 with a difference of 97%. These values represent a best estimation of the amount of NO₃-N that was biologically removed by the buffer in the 1.5 m (5 ft) deep groundwater and translated to a mean potential biological percent removal of about 53%. Figure 26 also shows a slight increase in stream edge Cl⁻ concentrations after the beginning of 2008 which would seem to indicate that less groundwater mixing was occurring during this period. The data was split into pre-2008 and post-2008 periods and analyzed in the same manner to determine the biological uptake for each period. The post-2008 period did have a slightly higher percent potential biological

uptake of about 63% while the pre-2008 period was found to have a lower percent biological removal of 44%.

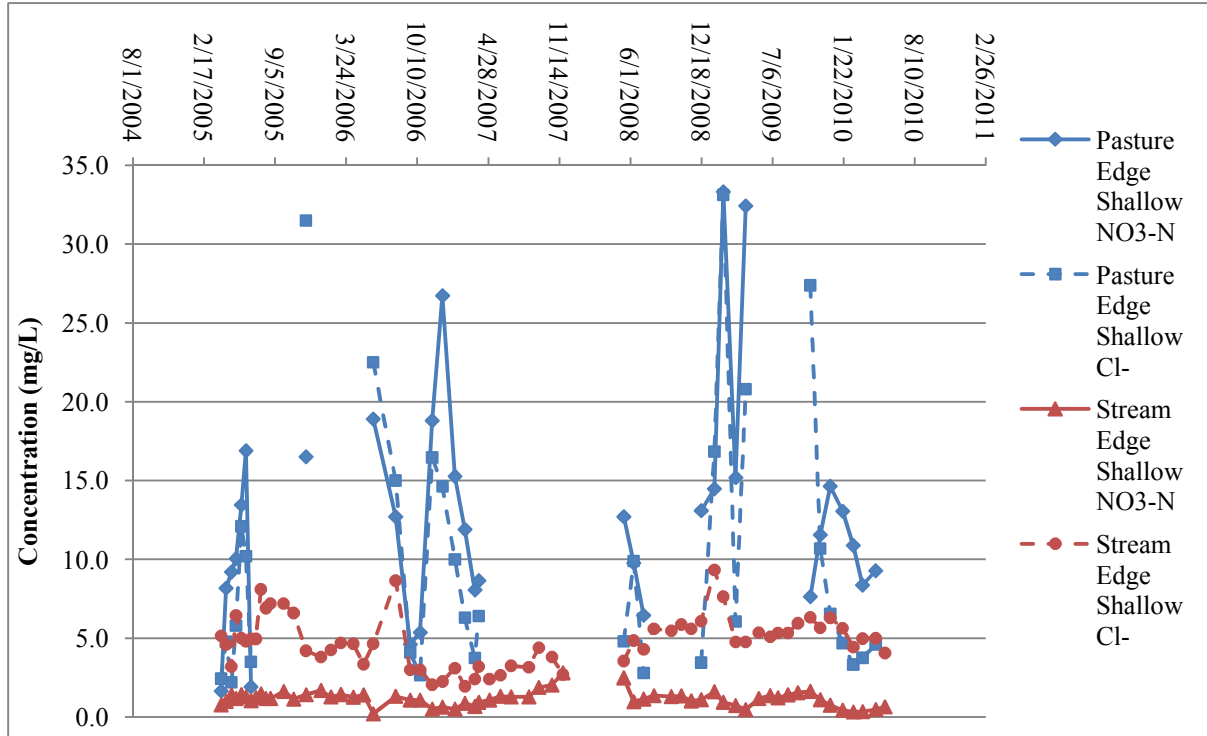


Figure 26. Block 1 mean pasture edge and stream edge NO₃-N and Cl⁻ concentrations in groundwater at the shallow depth (1.5 m) for each sampling date throughout the monitoring period. Note: range of y-axis was minimized by omitting the following dates from the figure but not from the analysis: 1/12/2006, 2/9/2006, and 3/9/2006

A similar analysis was performed for the 3.0 m (10 ft) groundwater wells in Block 1. The mean of groundwater NO₃-N and Cl⁻ concentrations for all pasture edge deep (3.0 m (10ft) depth) groundwater and stream edge (3.0 m (10 ft) depth) groundwater were calculated for each sampling date. The means were then plotted throughout the entire monitoring period as shown in Figure 27. One sampling date, 4/22/2008, was removed because the extremely high Cl⁻ concentrations at the pasture edge (values ranged from 20.0 mg/L to 186.8

mg/L) so that the plot was at a scale more easily viewed. The figure shows that both NO₃-N and Cl⁻ concentrations in groundwater decreased between the pasture edge and the stream edge for a majority of the monitoring period. All 60 of the paired NO₃-N samples decreased between the pasture edge groundwater and stream edge groundwater. Many of the decreases were substantial; 47 of the 60 samples decreased by more than 5 mg/L and half of the paired samples (30 out of the 60 total samples) decreased by more than 10 mg/L. The reduction in NO₃-N concentration between the pasture edge groundwater and the stream edge groundwater ranged from 71% to 91% and the mean and median reductions were 88% and 89% respectively.

Similarly, all 60 of the paired Cl⁻ samples decreased between the pasture edge deep (3.0 m (10ft) depth) groundwater and stream edge deep (3.0 m (10 ft) depth) groundwater. However, many of the reductions in Cl⁻ concentrations were smaller than the decreases found in NO₃-N concentrations. Forty of the 60 paired Cl⁻ samples decreased by more than 5 mg/L but only 8 of the paired samples decreased by more than 10 mg/L. The reduction in Cl⁻ concentration between the pasture edge groundwater and stream edge groundwater ranged from 23% to 86% while the mean and median reductions were 62% and 61% respectively.

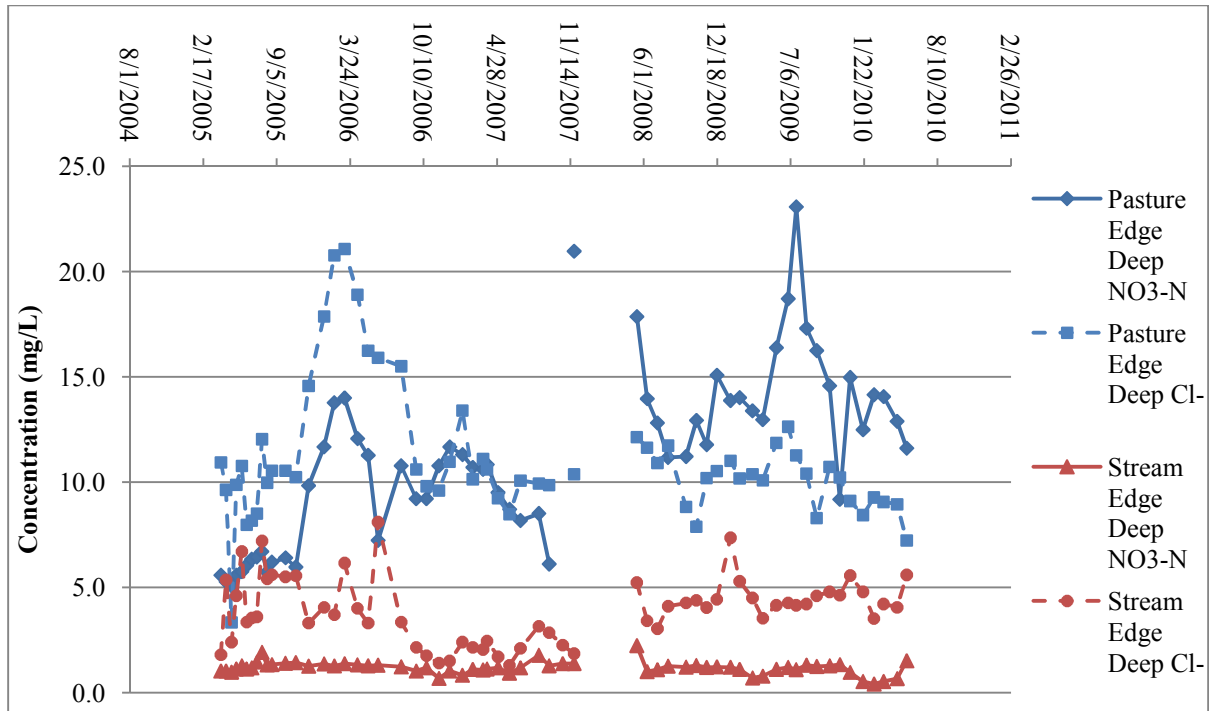


Figure 27. Block 1 mean pasture edge and stream edge NO₃-N and Cl⁻ concentrations in groundwater at the deep depth (3.0 m) for each sampling date throughout the monitoring period. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: 4/22/2008

The same analysis that was completed for shallow 1.5 m (5 ft) depth groundwater was repeated for the deep 3.0 m (10 ft) depth groundwater to determine the amount that biological processes may have contributed to the decreases in NO₃-N concentration. Table 20 found in Appendix D shows values calculated for each sampling date. The mean difference between the percent reduction in NO₃-N concentrations and the percent reduction Cl⁻ concentrations was 26% and the median was 28%. The maximum difference was 64% which occurred on 5/18/2010. These values were approximately the amount of reduction in NO₃-N concentrations that could be attributed to biological removal in the buffer at the deep depth.

The data was again split into a pre-2008 and post-2008 groups and analyzed due to the slight changes between the two periods. The post-2008 period had again had a higher biological removal of 38%, while a percent reduction of 17% was calculated for the pre-2008. It is unknown why such a large discrepancy occurred between these two periods of the study.

These removals were less than what was been reported by previous researchers who calculated removals of between 75-99% (Altman and Parizek, 1995; Schoonover and Williard, 2003; Vellidis et al., 2003). However, the values are similar to those found by Clausen et al (2000) who reported a 35% N removal in the buffer groundwater, as well as, Dukes et al. (2002) and Snyder et al. (1998) who reported ranges of 28-84% and 16-70% respectively due to variability among buffers within each of their own studies. All of these studies accounted for dilution using some form of tracer except Snyder et al. (1998).

Groundwater Quality – Cations

Decreasing Cl⁻ concentrations seemed to indicate that significant groundwater mixing occurred in the Block 1; however more evidence was sought to confirm this conclusion. Cations were assessed at the pasture edge wells and stream edge wells in the surficial groundwater and in the deep groundwater wells that were installed below the saprolitic layer in an attempt to establish a difference in chemistry between the saprolitic aquifer and surficial aquifer. If unique chemistries were found between the two aquifers then it would have been possible to conclude that the two aquifers were separated and very little dilution was taking place. Likewise, if the two aquifers had the same chemistries throughout the

buffer or at a particular location in the buffer then it might indicate that there was no separation and dilution was occurring in that area of the buffer.

Figure 28 shows the concentrations of Na^+ cations in Block 1 based on the approximate elevation of the well screen at the site. Elevations above 55.0 m (180 ft) indicated wells that were in the surficial aquifer, wells below this elevation were screened in the saprolitic soil layer and considered a part of the deep aquifer. Na^+ concentrations ranged from 1.2 mg/L to about 24.0 mg/L over the monitoring period. No real trend with groundwater elevation could be found as Na^+ concentrations overlapped considerably among the different groundwater elevations. As a result, no groundwater signature could be assigned to the surficial or deep aquifer and no separation of the aquifers could be determined. This indicated that mixing between the elevations was a possibility.

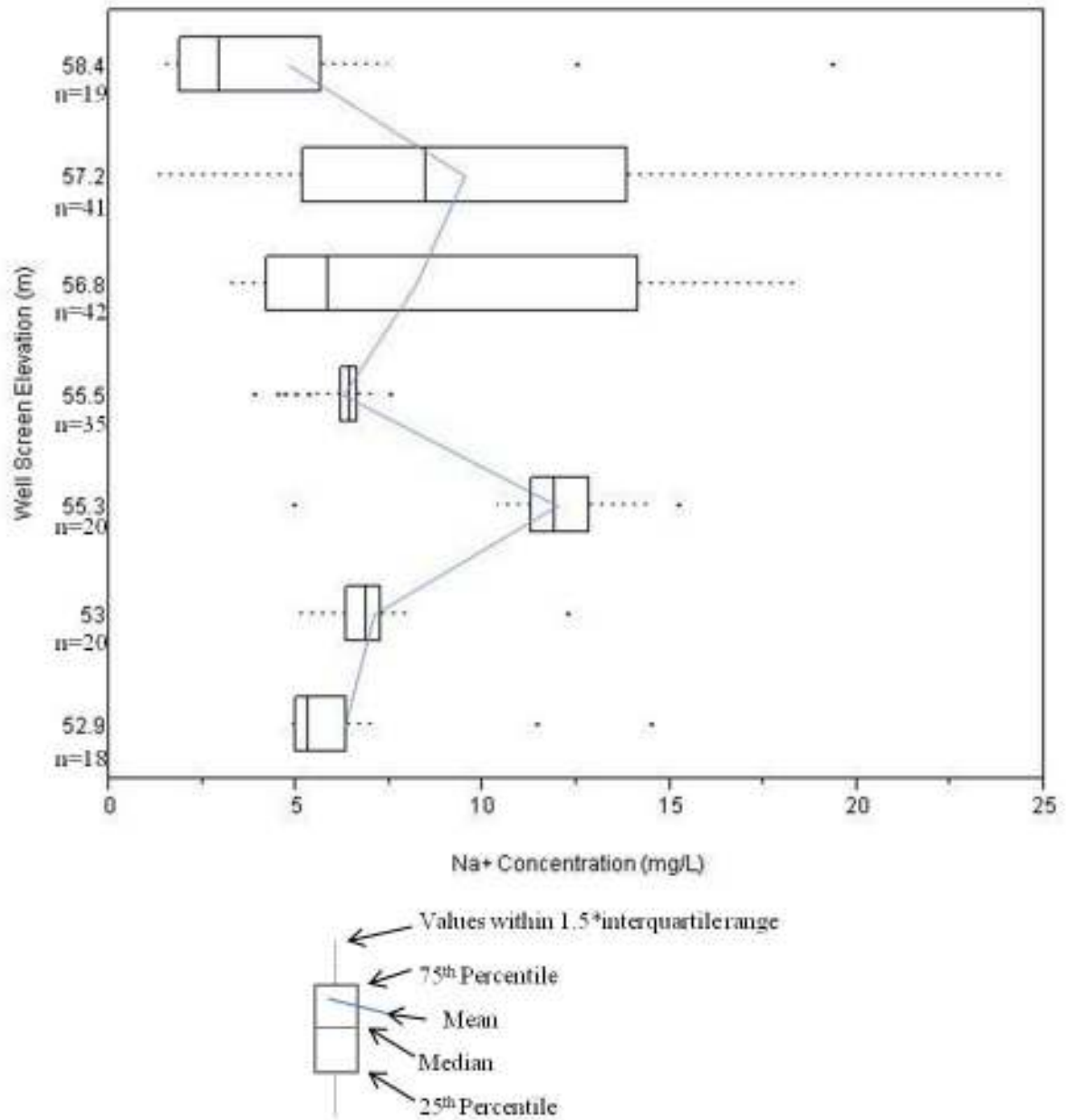


Figure 28. Block 1 Na⁺ concentrations at various well depths below the ground surface. Lines represent trends between means for each well position.

Ca²⁺ cations were analyzed in the same manner and are displayed in Figure 29. Ca²⁺ cations ranged from 0.0 mg/L up to 50.8 mg/L over the monitoring period. The only groundwater that seemed to have a very different concentration was the deepest well, with a well screen elevation of 52.9 m (174 ft), which had a Ca²⁺ concentration that was consistently lower than the other groundwater elevations. This well was located in the pasture, up gradient from Block 1, and the well screen was installed 9.6 m (32 ft) below the ground surface. The data indicates that groundwater located there may be different from the groundwater moving through the buffer. However, no trend between the wells actually located in Block 1 was found.

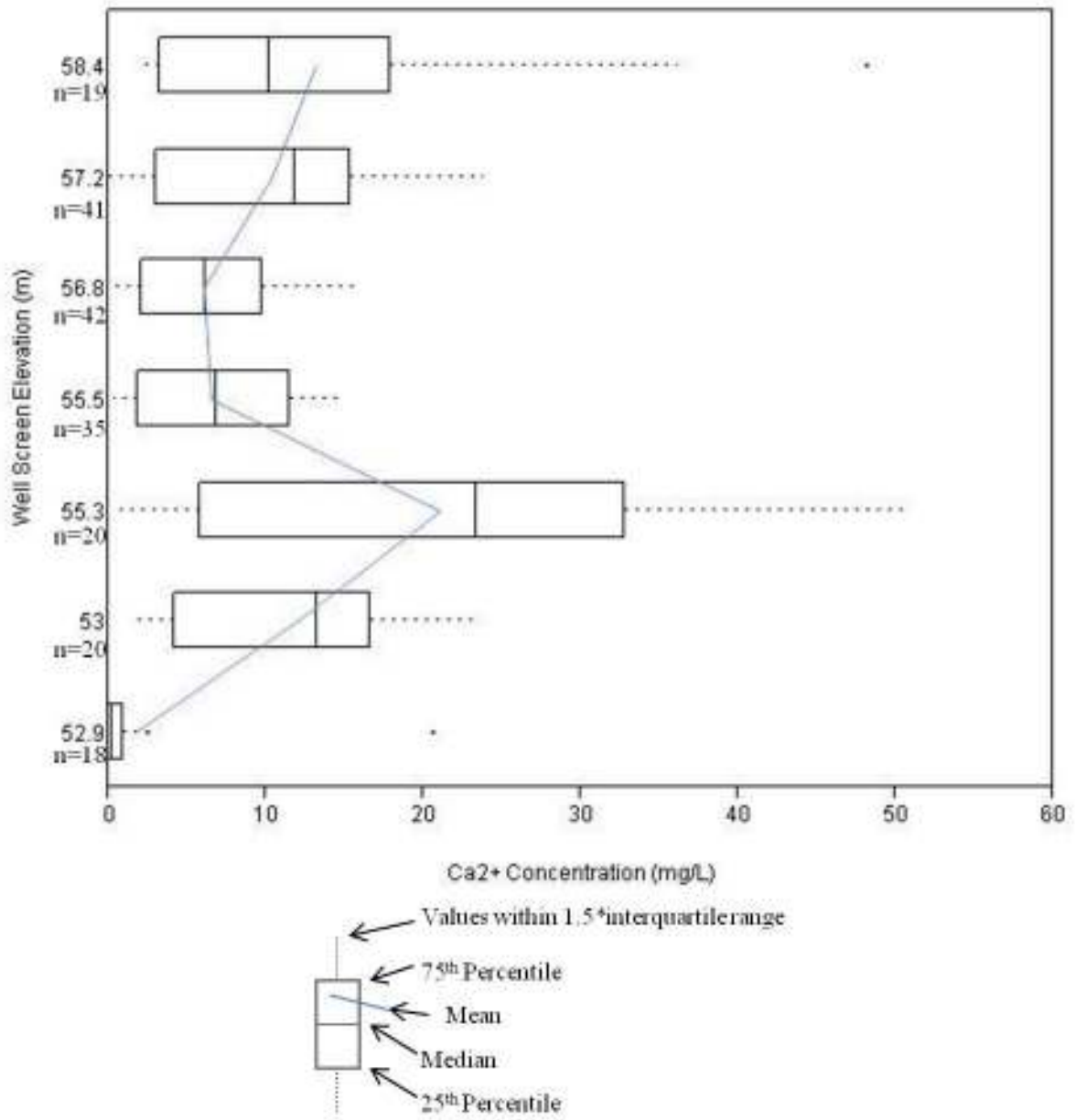


Figure 29. Block 1 Ca²⁺ Concentrations at various well depths below the ground surface. Lines represent trends between means for each well position.

Discussion and Conclusion

Significant reductions in $\text{NO}_3\text{-N}$ concentrations occurred between the pasture edge groundwater and stream edge groundwater; a mean percent reduction in $\text{NO}_3\text{-N}$ of 94% for shallow 1.5 m (5 ft) depth groundwater and 89% for deep 3.0 m (10ft) depth groundwater over the monitoring period were recorded. Similarly, calculated $\text{NO}_3\text{-N}$ loads were reduced substantially between the pasture edge groundwater and stream edge groundwater in the buffer. Ideally this reduction in $\text{NO}_3\text{-N}$ would have been due to denitrification in the buffer which would have resulted in complete removal of the $\text{NO}_3\text{-N}$ from the system. There were indications that conditions were favorable for denitrification, however, there was also evidence that dilution of concentrations by groundwater mixing was partially responsible for the decreases in $\text{NO}_3\text{-N}$ concentrations.

Other measurements also indicated that conditions in the buffer were conducive for denitrification to occur throughout the monitoring period. Residence time for groundwater in the monitoring block was estimated to be over 10 years, which should have been adequate for denitrification to occur. At the deep depth, a majority of all redox measurements recorded in the buffer were below the +200 mV threshold where denitrification is thought to be a primary process. Below threshold redox levels were also recorded from redox probes in the shallow depth, but far less frequently than the deep probes. This was attributed to the water table dropping below the elevation of the shallow probes during dry periods creating aerobic conditions around the probe and making denitrification less likely due to fewer O_2 depleted

pore space. Rarely were mean redox measurements above +350 mV, where denitrification has been shown to occur, for both shallow and deep probes.

Mean DOC concentrations in Block 1 were probably marginal for high rates of denitrification to occur and DOC concentrations may have been one of the limiting factors for denitrification. However, spikes of DOC to concentration of nearly 10 mg/L or above, where high rates of denitrification have been measured by other researchers (Obenhuber and Lowrance, 1991), occurred throughout the year.

However, these measurements did not account for groundwater mixing, changing flow volumes, or preferential flow paths that could have played a role in the decreasing NO₃-N concentrations. For this reasons, NO₃-N concentrations normalized by Cl⁻ concentrations were thought to be a better indicator of the fate of NO₃-N. Chloride concentrations were found to significantly decrease between the pasture edge groundwater and stream edge groundwater for both the 1.5 m (5 ft) and 3.0 m (10 ft) depths, which indicated that not all of the reduction in NO₃-N concentrations was due to biological processes (denitrification or vegetation uptake) but a significant amount was also caused by dilution by a Cl⁻ poor aquifer.

Chloride concentration in groundwater at the 1.5 m (5ft) and the 3.0 m (10 ft) depth both decreased significantly between the pasture edge and the stream edge. Analysis of samples on each sampling date indicated that these reductions occurred for a majority of the sampling period, however, the reductions in Cl⁻ concentrations were on average not as large as the decreases in NO₃-N concentrations between the pasture edge groundwater and stream

edge groundwater. At the 1.5 m (5ft) groundwater depth NO₃-N concentrations decreased on average by 6.5 mg/L more than Cl⁻ concentrations. At the 3.0 m (10 ft) groundwater depth the decrease was 3.0 mg/L. Assuming that the dilution source had nearly the same effect on both NO₃-N and Cl⁻ concentrations the difference in decreases between concentrations was thought to be the maximum amount of reduction in NO₃-N concentrations that could be attributed to biological transformation, most likely by denitrification. The reduction of NO₃-N attributed to denitrification was calculated to be 51% and 27% for the 1.5 m (5 ft) and 3.0 m (10 ft) groundwater depths respectively.

It should be noted that Cl⁻ concentrations fluctuated greatly at the pasture edge during the monitoring period. Often Cl⁻ concentrations tracked very nearly with NO₃-N concentrations although not in all cases and the variability made interpretation of the data with high confidence difficult. Variability of Cl⁻ concentrations at the pasture edge were thought to be due to both the variability in the poultry litter source as well as possible uneven application of the litter to the pasture. This seemed to be a major drawback to the NO₃-N / Cl⁻ technique at this site. Despite these difficulties, data indicated that both dilution and denitrification of NO₃⁻ likely occurred in Block 1. Future work researching this monitoring block or other riparian buffers should take these findings into account and possibly use other techniques to account for dilution and denitrification.

While dilution due to groundwater mixing is not the preferred process of NO₃-N concentration reduction in riparian buffers, Block 1 may have still had an important role in

improving water quality. The $\text{NO}_3\text{-N}$ load entering the stream would have likely been greater if the pasture had extended all the way to the edge of the stream due to increased surface runoff and an increase in the $\text{NO}_3\text{-N}$ laden contributing area. The buffer acted as a barrier to surface runoff and a physical area where almost no additional $\text{NO}_3\text{-N}$ was added to the groundwater so that $\text{NO}_3\text{-N}$ concentrations, from the pasture, could be diluted or transformed.

It's important to note that further $\text{NO}_3\text{-N}$ losses may have occurred as groundwater was being discharged through the hyporheic zone of the stream. Significant denitrification has been observed in other studies in this area of riparian buffers (Spruill, 2000). This would have increased the effectiveness of the buffer.

Other future work in this monitoring block could investigate the effect of the stream incision on the buffer effectiveness. As mentioned in the site description, the stream was incised between 1.2-1.5 m (4-5 ft) throughout Block 1, lowering the water table in the block especially along the stream edge. High water tables are considered an important characteristic of riparian buffers when NO_3^- reduction in groundwater is a major goal. In Block 1, higher water tables could provide anaerobic conditions for a higher percent of each year and could possibly increase DOC concentrations in groundwater by leaching carbon from the upper horizons of the soil which could possibly translate to higher overall denitrification rates.

References

- Addy, K.L.; Gold, A.J.; Groffman, P.M.; Jacinthe, P.A. 1999. Ground water nitrate removal in subsoil of forested and mowed riparian buffer zones. *Journal of Environmental Quality* 28, 962-970.
- Ambus, Per and Lowrance, Richard. 1991. Comparison of denitrification in two riparian soils. *Soil Science Society of America Journal* 55(4), 994-997.
- Altman, S.J. and R.R. Parizek. 1995. Dilution of nonpoint-source nitrate in groundwater. *Journal of Environmental Quality* 24, 707-718.
- Aravena, R. and W.D. Robertson. 1998. Use of multiple isotope tracers to evaluate denitrification in ground water: Study of nitrate from a large-flux septic system plume. *Groundwater* 36 (6), 975-982.
- Bailey, L.D., and E.G. Beauchamp. 1973. Effects of moisture, added NO_3^- , and macerated roots on NO_3^- transformation and redox potential in surface and subsurface soils. *Canadian Journal of Soil Science* 53(2), 219-230.
- Beaulac, M.N., and K.H. Reckhow. 1982. An examination of land use – nutrient export relationships. *Water Resources Bulletin* 18 (6), 1013-1024.
- Böhlke, J.K. and Denver, J.M. 1995. Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland. *Water Resources Research* 31(9), 2319-2339.
- Christensen, T.H., Bjerg, P.L., Banwart, S.A., Jakobsen, R., Heron, G. Albrechtsen, H. 2000. Characterization of redox conditions in groundwater contaminant plumes. *Journal of Contaminant Hydrology* 25, 165-241.
- Clausen, J.C., Guillard, K., Sigmund, C.M., Dors, K. Martin. 2000. Water quality changes from riparian buffer restoration in Connecticut. *Journal of Environmental Quality* 29(6), 1751-1761.
- Dukes, M.D.; Evans, R.O.; Gilliam, J.W.; Kunickis, S.H. 2002. Effect of riparian buffer width and vegetation type on shallow groundwater quality in the middle coastal plain

- of North Carolina. *Transactions of the American Society of Agricultural Engineers* 45(2), 327-336.
- Fieldler, S., M.J. Vepraskas, and J.L. Richardson. 2007. Soil redox potential: Importance, field measurements, and observations. *Advances in Agronomy* 94, 1-54.
- Gillham, R.W., R.C. Star, D.J. Miller. 1990. A Device for in-situ determination of geochemical transport parameters. *Groundwater* 28 (6). 858-862.
- Hill, A.R. 1996. Nitrate removal in stream riparian zones. *Journal of Environmental Quality* 25, 743-755.
- Hubbard, R.K.; Newton, G.L.; Davis, J.G.; Lowrance, R.; Vellidis, G.; Dove, C.R. 1998. Nitrogen assimilation by riparian buffer systems receiving swine lagoon wastewater. *Transactions of the American Society of Agricultural Engineers* 41(5), 1295-1304.
- Kilmer, V.J., J.W. Gilliam, J.F. Lutz, R.T. Joyce, and C.D. Eklund. 1974. Nutrient losses from fertilized grassed watersheds in Western North Carolina. *Journal of Environmental Quality* 3 (3), 214-219.
- Knowles, R., 1982. Denitrification. *Microbiological Reviews* 46 (1), 43-70.
- Kralova, M., P.H. Masscheleyn, C.W. Lindau, W.H. Patrick, Jr. 1992. Production of dinitrogen and nitrous oxide in soil suspensions as affected by redox potential. *Water, Air, and Soil Pollution* 61, 37-45.
- Larsen, D., R.W. Gentry, and D.K. Solomon. 2002. The geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA. *Applied Geochemistry* 18, 1043-1063.
- Line, D.E., W.A. Harman, G.D. Jennings, E.J. Thompson, and D.L. Osmond. 2000. Nonpoint-source pollutant load reductions associated with livestock exclusion. *Journal of Environmental Quality* 29, 1882-1890.

- Line, D.E., N.M. White, D.L. Osmond, G.D. Jennings, and C.B. Mojonnier. 2002. Pollutant export from various land uses in the upper Neuse River Basin. *Water Environment Research* 74 (1), 100-108.
- Martin, T.I.; Kaushik, N.K.; Trevors, J.T.; Whiteley, H.R. 1999. Review: Denitrification in temperate climate riparian zones. *Water, Air, and Soil Pollution* 111, 171-186.
- Mengis, M.; Schiff, S.L.; Harris, M.; English, M.C.; Aravena, R.; Elgood, R.J.; MacLean. 1999. Multiple geochemical and isotopic approaches for assessing ground water NO₃⁻ elimination in a riparian zone. *Ground Water* 37(3), 448-457.
- Natural Resource Conservation Service. 2008. Web soil survey: Halifax County, NC. Available at <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>. Accessed on April 15, 2009.
- Nicholson, F.A., B.J. Chambers, and K.A. Smith. 1996. Nutrient composition of poultry manures in England and Wales. *Bioresource Technology* 58, 279-284.
- Obenhuber, D.C. and R. Lowrance. 1991. Reduction of nitrate in aquifer microcosms by carbon additions. *Journal of Environmental Quality* 20(1), 255-258.
- Puckett, L.J. 2004. Hydrogeologic controls on the transport and fate of nitrate in ground water beneath riparian buffer zones: Results from thirteen studies across the United States. *Water Science and Technology* 49(3), 47-53.
- Rawls, W.J., D. Gimenez, and R. Grossman. 1998. Use of soil texture, bulk density, and slope of water retention curve to predict saturated hydraulic conductivity. *Transactions of the ASAE* 41 (4), 983-988.
- Saxton, K.E. and W.J. Rawls. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *United States Department of Agriculture and Washington State University*. Accessed at <http://hydrolab.arsusda.gov/SPAW/Index.htm>.

- Schoonover, Jon E.; Williard, Karl W.J. 2003. Ground water nitrate reduction in giant cane and forest riparian buffer zones. *Journal of the American Water Resources Association* 39(2), 347-354.
- Schwartz, F.W. and H. Zhang. 2003. *Fundamentals of Groundwater*. New York, N.Y.: John Wiley and Sons.
- Sóvik, A.K. and P.T. Mørkved. 2007. Nitrogen isotope fractionation as a tool for determining denitrification in constructed wetlands. *Water Science and Technology* 56 (3), 167-173.
- Spruill, Timothy B. 2000. Statistical evaluation of effects of riparian buffers on nitrate and ground water quality. *Journal of Environmental Quality* 29, 1523-1538.
- State Climate Office of North Carolina. Enfield Weather Station (ID# 312827). *North Carolina Climate Retrieval and Observations Network of the Southeast Database (NC CRONOS)*. Accessed at <http://www.nc-climate.ncsu.edu/services/request.php>.
- Starr, R.C. and R.W. Gillham. 1993. Denitrification and organic carbon availability in two aquifers. *Groundwater* 31(6), 934-947.
- Stefansson, A., S. Arnorsson, A.E. Sveinbjornsdottir. 2005. Redox reactions and potential in natural waters at disequilibrium. *Chemical Geology* 221, 289-311.
- United States Army Corps of Engineers. 1987. Corps of Engineers Wetland Delineation Manual. Accessed at <http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf>.
- Van Beers, W.F.J. 1958. The auger hole method: A field measurement of the hydraulic conductivity of soil below the water table. *International Institute for Land Reclamation and Improvement*. 1-23.
- Vellidis, G.; Lowrance, R.; Gay, P.; Hubbard, R.K. 2003. Nutrient transport in a restored riparian wetland. *Journal of Environmental Quality* 32, 711-726.
- Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA-FS publication No. NA-PR-07-91.

Radnor, Pa.: USDA-FS. Accessed at
http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm.

Wafer, C.C., R.J. Barrett, and D.L. Osmond. 2004. Construction of platinum-tipped redox probes for determining soil redox potential. *Journal of Environmental Quality* 33 (6), 2375-2379.

Zublena, J.P., J.C. Barker, T.A. Carter. 1996. Poultry manure as a Fertilizer source. *North Carolina Cooperative Extension Service*. Pub. No. AG-439-5. Accessed at:
http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag439_5.html

CHAPTER 3: FATE OF NITRATE AND HYDROLOGY OF MONITORING BLOCK 2

Introduction

The goal of this study was to apply several measurement techniques to a CREP enrolled buffer and determine the fate of groundwater NO_3^- as it moved through the buffer. Understanding the fate and transport of NO_3^- at the field scale will lead to better buffer design and placement in the landscape. If individual processes can be linked to easily measurable characteristics of the buffer, generalized rapid assessment techniques should become more accurate and feasible. Then planners will be able to better allocate resources to those buffers that are predicted to have the greatest affect on improving water quality. Due to the variability between buffers at different sites, and even differences in buffers at the same site, many detailed studies that assess both biological removal of NO_3^- and dilution of NO_3^- concentrations will need to be performed before accurate general guidelines can be established. With this in mind, the analysis that was performed in Chapter 2 was repeated in a different area of the buffer to determine how the effectiveness of the buffer might vary. A new monitoring block, Block 2, was established at a higher elevation than Block 1, but with the same dimensions and instrumentation as Block 1.

Materials and Methods

Site Description

Block 2 was just upstream from Block 1 along Ruth's Branch, near the middle of the monitoring site as shown in Figure 4. Up-gradient from the buffer the pasture slope was about 0.047, similar to Block 1, and the application rate of $\text{NO}_3\text{-N}$ was the same, about 41 kg-N/ha. The contributing area was estimated to be 3.5 ha, approximately 1 ha larger than Block 1. Block 2 also had significant stream incision of between 1.1 m and 1.4 m (3-5 ft) from the top of the stream bank, especially in the downstream part of the block (near transects A and B).

Soils Description

NRCS soils survey (NRCS, 2008) showed the soils were similar to Block 1, Goldsboro fine sandy loam within the buffer and a mix of Bonneau loamy fine sand and Emporia-Wedowee sandy loam complex in the pasture.

Soil cores taken at the site showed that soils in the pasture upslope from Block 2 consisted of clayey silts near the surface with some fine sand that extended to a depth of about 2.4 m (8.0 ft) below the ground surface. A clayey silt saprolite layer occurred below this depth and continued to auger refusal. Soils inside the buffer at the pasture edge were sandy near the ground surface with small and medium gravels. Clay and silt increased at a depth of about 1.8 m (6.0 ft) with bands of course sand and gravels also occurring in this layer until a depth of about 3.7 m (12.0 ft) where a silt saprolite layer similar to the layer

found in the pasture occurred. This layer continued until auger refusal at 14.0 m (46.0 ft), the deepest depth that a soil sample was taken in this study. At the stream edge of Block 2 a clayey sand horizon occurred to a depth of (4 ft) followed by a clayey silt horizon down to a depth of about 3.7 m (12 ft) where the silt saprolite layer began and continued to the bottom of the core. Figure 30 shows the soil textures at different topographic positions in Block 2.

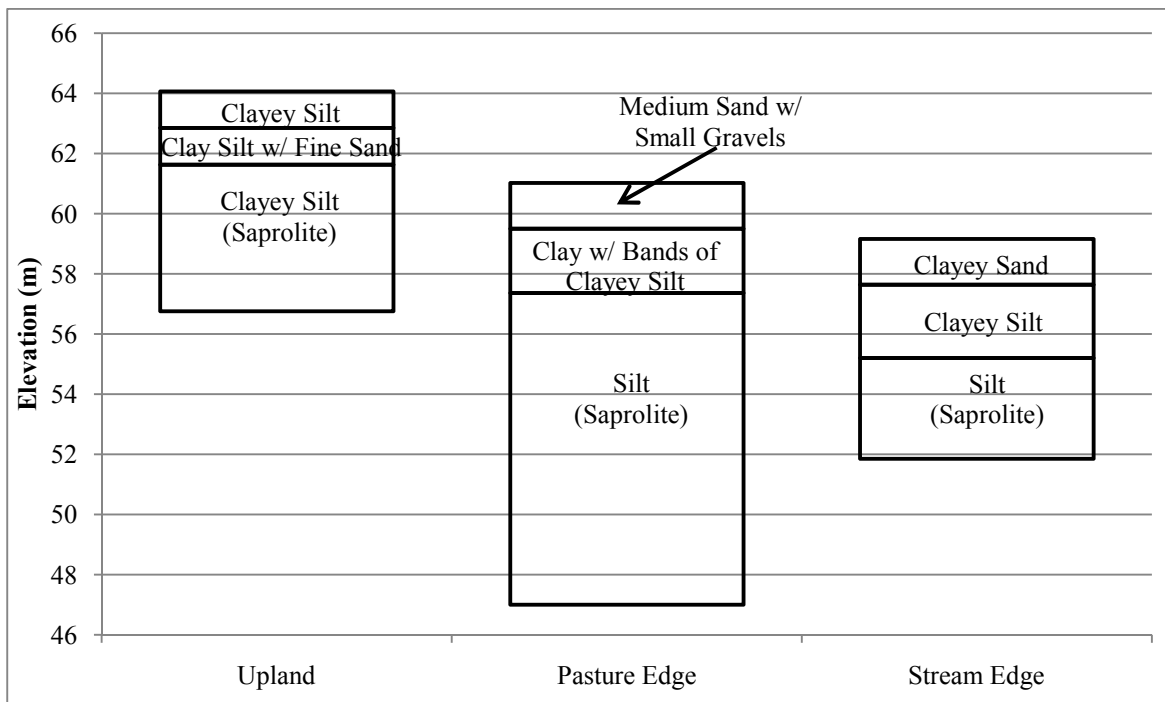


Figure 30. Block 2 soils at different topographic locations

Monitoring

Figure 31 shows the monitoring layout for Block 2. The instrument and monitoring well layout was similar to Block 1 except that Block 2 had deep 3 wells at all well positions. Surficial aquifer wells were installed at the same time and in the same manner as Block 1

(See Groundwater Monitoring Section in Chapter 2). Shallow wells were installed at a depth of 1.5 m (5 ft) below the ground surface and deep wells were installed at 3.0 m (10 ft) below the ground surface. Plots in this chapter may have select water quality data removed to improve clarity. The location of the removed data will be noted in the caption under each graph using the following method: PE denotes pasture edge (well position 1), MB denotes the mid-buffer (well position 2), and SE denotes the stream edge (well position 3). The depth of each well was also included with S denoting the shallow depth (1.5 m depth) and D denoting the deep depth (3.0 m).

Redox potential probes were located at each well position in transect B and were installed at the same depths below the ground surface as the shallow and deep wells. Water table depth loggers were positioned at the pasture edge and stream edge locations.

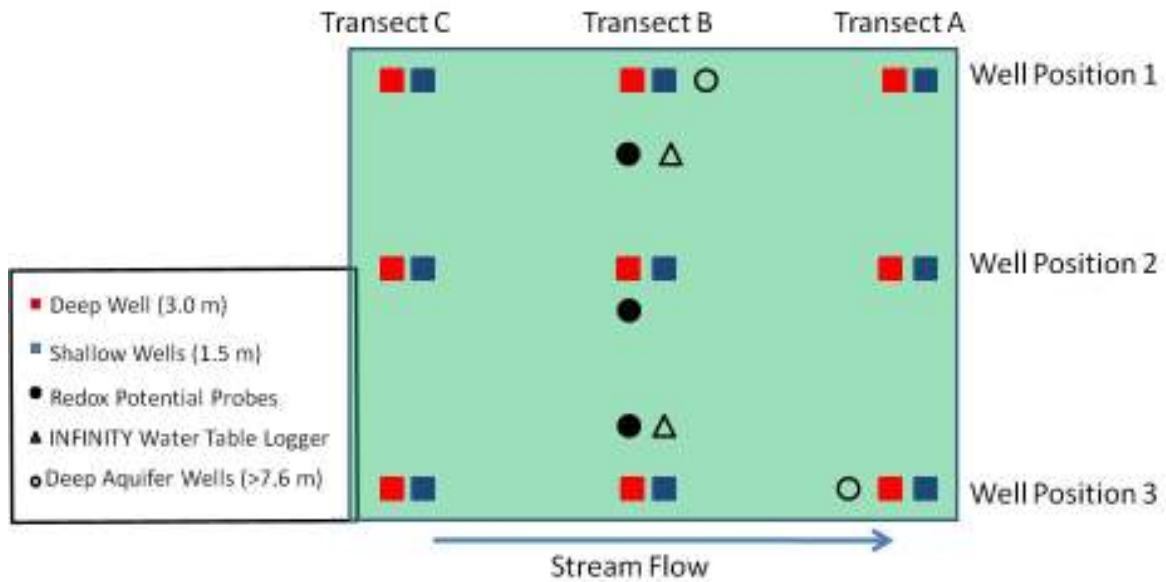


Figure 31. Block 2 monitoring well and instrumentation layout.

Deep aquifer wells in Block 2 were installed at the same time as those in Block 1 using the same protocol. One well was placed in the pasture, upslope from the monitoring block and was installed 9.8 m (32 ft) below the ground surface, into the saprolitic soil layer at the site. Two other deep aquifer wells were placed inside the monitoring block, one at the pasture edge in transect B and one at the stream edge in transect A. The deep aquifer pasture edge well was installed to a depth of 9.4 m (31 ft) below the ground surface and the stream edge deep aquifer well was installed to a depth of 7.6 m (25 ft) below the ground surface. Figure 32 shows a profile view of Block 2 and the location and depth of the monitoring wells.

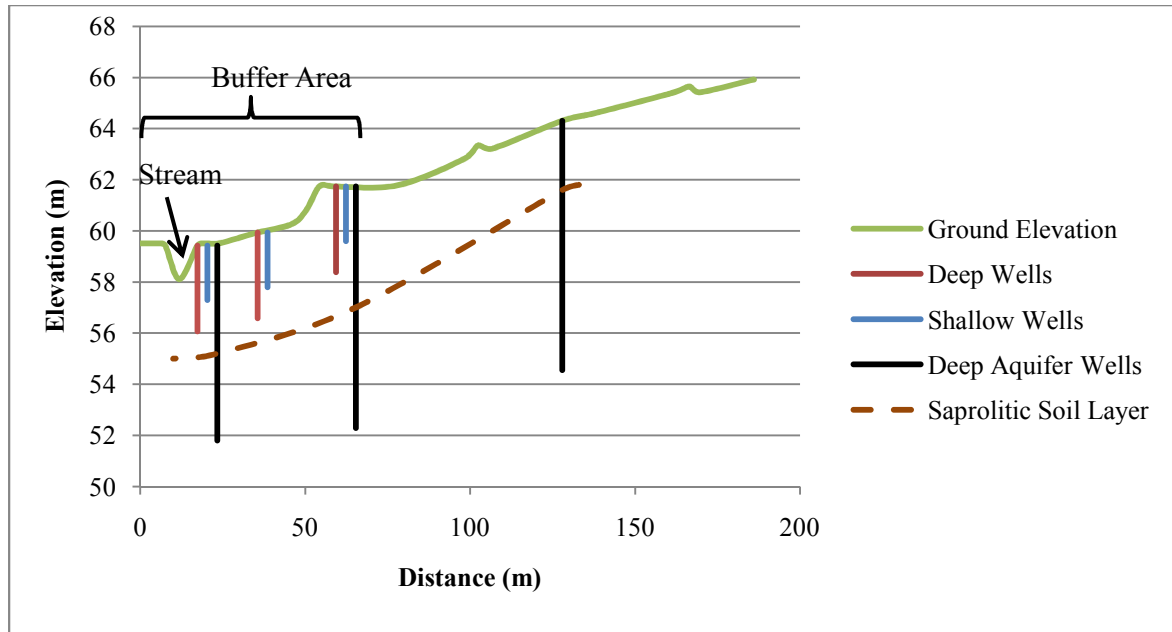


Figure 32. Block 2 profile and surficial and deep aquifer locations and depths.

All groundwater wells and water level data loggers were constructed and installed in the same manner as those in Block 1 (See Water Table Measurements in Chapter 2). Groundwater quality sampling in Block 2 used the same protocols and sampling frequencies that were reported for Block 1 in Table 1 (See Groundwater Quality Sampling in Chapter 2). Soil samples were also obtained in the same manner as those procedure reported in Chapter 2 (See Soil Sampling in Chapter 2), except that DEA samples were only taken in the transect B of Block 2, instead of samples being taken in transects A and transect C. Redox probe installation and measurements were also the same in Block 2 as those found in Block 1 (See Redox Potential Probes Section in Chapter 2). Redox probes were installed at the same depths as the shallow and deep water quality wells

Load and Residence Time Calculations

NO₃-N loads and residence time were calculated for the monitoring period for both the shallow and deep surficial monitoring well using the same formulas and methods found in Chapter 2 with some small exceptions (See Flux and Load Calculations and Residence Time Calculations in Chapter 2). Saturated hydraulic conductivities were obtained from Table 7 below and the datum's used in calculating Darcy's law were changed to reflect the higher elevations in Block 2. The deep layer datum was set at an elevation of 54.9 m (180 ft) and the shallow layer datum was set to 57.0 m (187 ft).

Results

Particle Size and Hydraulic Conductivity

To obtain saturated hydraulic conductivities for the site, first the auger hole method (Van Beers, 1970) was used. No measurements could be obtained in Block 3 due to the water table depth below the ground surface and equipment limitations. This method was abandoned for the Soil-Pond-Atmosphere-Water (SPAW) Field and Pond Hydrology model (Saxton, version 6.02.75) derived from research by Saxton and Rawls (2006). Using the soil-water characteristics function and the information gained from the particle size analysis of the buffer accurate hydraulic conductivities of individual samples were made.

Table 7 shows the sand content and the hydraulic conductivity found in Block 2. The 180 cm and 330 cm depths correspond to the approximate midpoint of the shallow 1.5 m (5 ft) and deep 3.0 m (10 ft) monitoring well screens. Unlike Block 1 no measurements could

be obtained using the auger hole method. At the sampling depth, the soils were progressively more sandy from the pasture edge to the stream edge and had increasingly higher saturated hydraulic conductivities.

Table 7. Block 2 Sand content and hydraulic conductivity at different depths below the ground surface

Depth Below Ground Surface	Pasture Edge		Mid-Buffer		Stream Edge	
	Sand (%)	Hydraulic Conductivity (cm/hr)	Sand (%)	Hydraulic Conductivity (cm/hr)	Sand (%)	Hydraulic Conductivity (cm/hr)
30 cm	81	10.7	86	10.4	70	7.0
50 cm	83	10.0	88	8.1	84	10.2
80 cm	74	2.2	83	5.9	87	11.7
180 cm	10	0.4	82	6.3	91	13.5
330 cm	24	0.9	44	1.8	89	8.3

Groundwater Hydrology

The pasture edge and stream edge water table loggers recorded depths for 94% of the total hours during the monitoring period, capturing a majority of the fluctuations in the water table. Figure 33 shows the water table at the pasture edge and stream edge for Block 2 in 2009. As expected, the water table was highest during the winter and early spring. It usually reached its lowest elevations during the autumn months. Late spring and summer months had an overall decreasing trend in water table elevations except when large rain events briefly raised the water table to elevations similar to those found in winter. Also of note are the infrequent negative gradients that occurred when the stream edge elevation was higher than the pasture edge elevation, this only occurred infrequently during the summer and

autumn months. Figure 33 is typical for all monitored years in Block 2 except 2006, which had higher water tables during the summer due to the tropical weather systems mentioned previously.

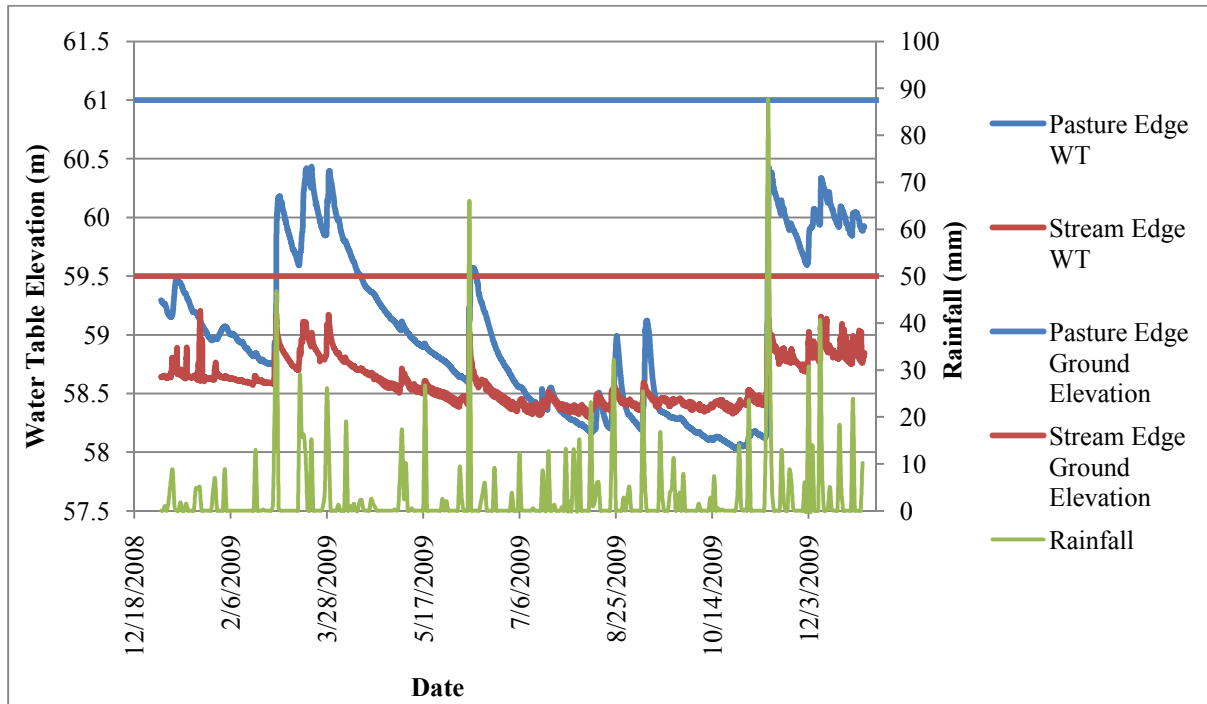


Figure 33. Block 2 water table elevations at the pasture edge and stream edge for 2009.

Water Table Proximity to Ground Surface

High water tables and saturated soils are often associated with denitrification because they typically create anaerobic and reduced soil conditions. Wetlands, for example, are identified as prime ecosystems for denitrification and high rates of NO_3^- removal. Analyzing the water table depth below the ground surface put the relative wetness of different areas of the buffer into perspective. Table 8 shows the percent of each year that the water table was

recorded at or above the specified depth from the ground surface. The water table at the pasture edge was rarely within 60 cm of the ground surface, while the stream edge rose above this depth slightly more frequently. A water table within 60 cm of the ground surface indicates that the water table was within the root zone. The root zone is significant because roots are thought to be a source of carbon to drive denitrification. Neither location met the hydrology requirements for wetland classification of the water table rising within 30 cm of the ground surface for 5% of the growing season (USACE, 1987). The year with the highest water table was 2006 which was also the year with the most rainfall. The other years were fairly similar in proximity to the ground surface.

Table 8. Water table proximity to the ground surface

Year	Pasture Edge			Stream Edge		
	0cm	30cm	60cm	0cm	30cm	60cm
2005	0%	0%	1%	0%	0%	13%
2006	0%	1%	5%	0%	1%	20%
2007	0%	0%	0%	0%	0%	10%
2008	0%	0%	2%	0%	0%	6%
2009	0%	0%	3%	0%	0%	11%
Mean	0%	0%	2%	0%	0%	12%

Groundwater Flow Direction

Manual water table readings from each water quality monitoring well were measured during multiple months in 2008 and 2009 and were inputted into SURFER 7 to determine groundwater flow direction within the buffer. Figure 33a shows the groundwater contours in April 2009, an example of a wet period, while Figure 33b shows the contours in August 2009, an example of a dry period. The groundwater topography in April shows the expected groundwater flow from pasture edge wells to stream edge wells, perpendicular to stream flow. In August the groundwater is flowing nearly parallel to the flow in the stream and the gradient is much lower. Block 2 displayed this flow pattern during several of the drier months of the year, between July and October, when gradients and water table elevations were low. However, groundwater flux calculations and groundwater quality analysis used the assumption of perpendicular flow through the buffer because the amount of each year that groundwater flowed parallel to the direction of stream flow was likely very short. This would have likely given a more conservative estimation of residence time

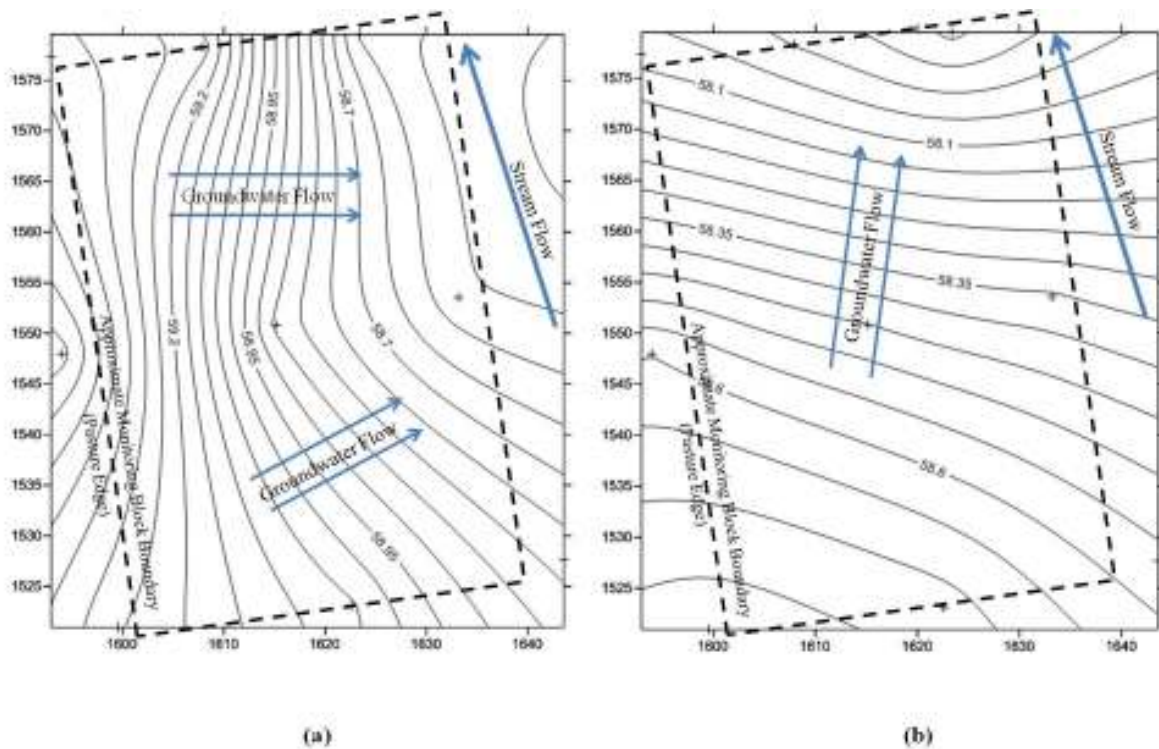


Figure 34. Block 2 flow directions in (a) April 2009 (wet period) and (b) August 2009 (dry period). Topographic lines represent elevations of the water table in meters. + signs indicate monitoring well locations where groundwater elevation was measured.

Residence Time

Residence time calculations for Block 2 indicated the minimum time for groundwater to move through the buffer was about 3.4 years. The maximum residence time could not be calculated because of negative gradients. A negative gradient indicates that water was flowing from the stream toward the pasture edge, meaning essentially that the water would never be discharged to the stream if the gradient remained at this value. About 20% of the

total measured gradients for Block 2 were negative, with a majority of the negative gradients falling between the months of July and November when the water table was at its lowest. The median residence time was 9.9 years while the mean was about 10.7 years. It is important to note that groundwater movement was not at a constant velocity through the buffer. Instead groundwater likely moved more rapidly during some parts of the year, then slowed down, possibly at times even flowing from the stream into the stream edge of the buffer, and as found in the groundwater direction flowed from the upstream part of the buffer to the downstream for brief periods. These details indicate that the mean and median residence times presented here were likely shorter than the actual residence times of the buffer.

Groundwater Quality – Nitrate (NO₃⁻)

Nitrate-nitrogen concentrations were sampled and assessed in the groundwater to determine if concentrations and loads decreased as the groundwater moved from the pasture edge to the stream edge. Figure 35 is a boxplot of shallow 1.5 m (5 ft) and deep 3.0 m (10 ft) groundwater NO₃-N concentrations in Block 2. The figure shows a large decrease in median concentration from the pasture edge (well position 1) to the mid-buffer (well position 2) for both depths. However, there is a slight increase in median concentrations between the mid-buffer and stream edge (well position 3) well positions. Despite this small increase, NO₃-N concentrations are much lower at the stream edge than the pasture edge indicating that some NO₃-N was being removed by vegetation, diluted by groundwater mixing, or removed via denitrification as the groundwater moved through the buffer.

Groundwater at the pasture edge had the largest range of concentrations compared to the other well positions. Shallow and deep pasture edge groundwater concentrations ranged from 0.1 mg/L to 23.1 mg/L. Shallow groundwater at the mid-buffer ranged from 0.0 mg/L to 10.2 mg/L and mid-buffer deep groundwater ranged from 0.0 mg/L to 6.9 mg/L. Finally, concentrations at the stream edge had the smallest range of sampled values ranging from 0.1 mg/L to 7.7 mg/L for shallow groundwater and from 0.1 mg/L to 3.9 mg/L for deep groundwater.

Mean concentration values were similar to the medians shown in Figure 35. The pasture edge mean concentration was 7.0 mg/L for shallow groundwater and 7.3 mg/L for deep groundwater. At the mid-buffer mean concentrations were 1.3 mg/L and 1.8 mg/L, while stream edge groundwater means were 2.1 mg/L and 1.3 mg/L for the shallow 1.5 m (5 ft) and deep 3.0 m (10 ft) groundwater depths respectively. These values corresponded to a percent mean reduction in concentrations of 70% and 82% for shallow groundwater and deep groundwater respectively from the pasture edge to the stream edge.

Statistical analysis showed that shallow and deep pasture edge groundwater was significantly different from the corresponding mid-buffer and stream edge groundwater. At the shallow 1.5 m (5 ft) depth the difference in concentrations between the mid-buffer and stream edge was also found to be significant. However, at the deep depth the difference between the mid-buffer and stream edge was not found to be statistically significant ($p = 0.0926$).

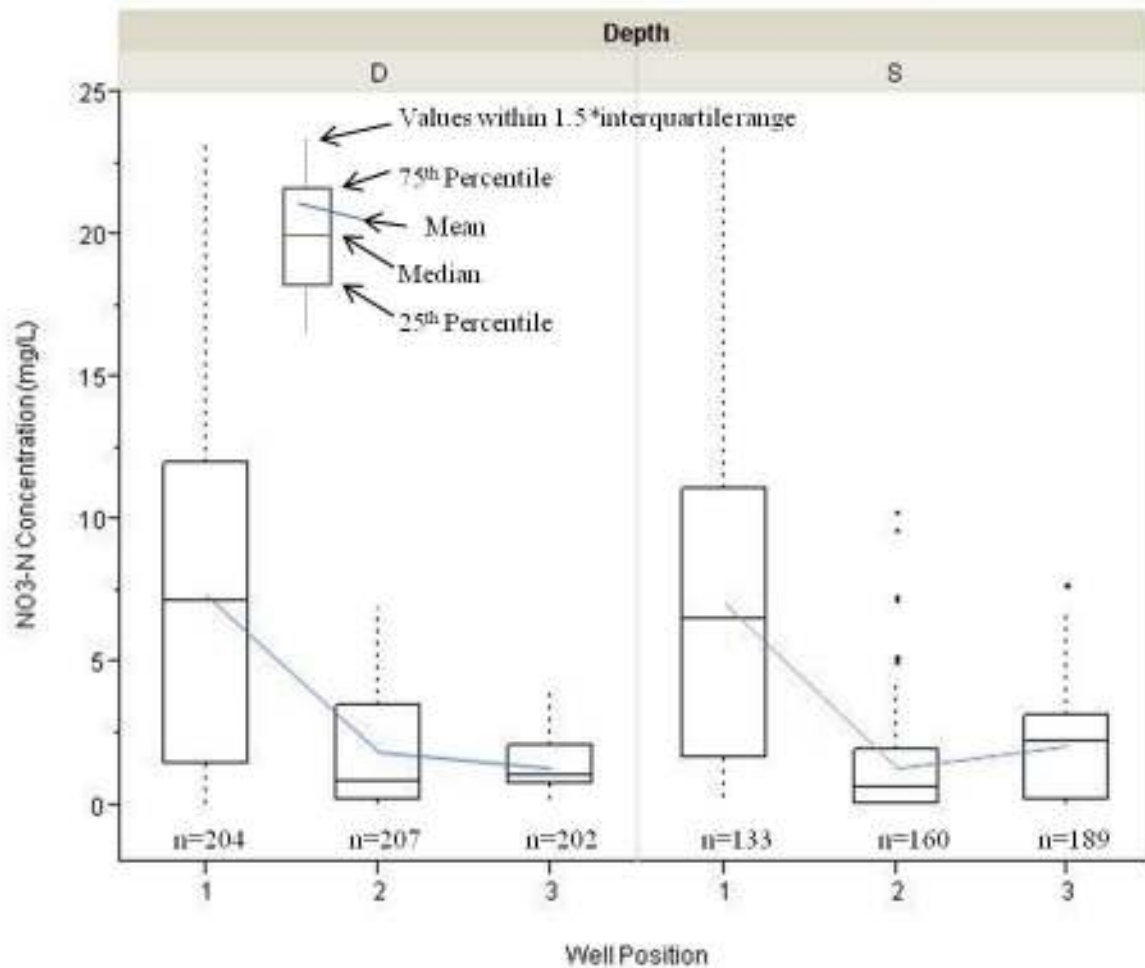


Figure 35. Block 2 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater NO₃-N concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between mean values at each well position.

Differences in well position concentrations between transects in Block 2 are shown in Figure 36 for shallow groundwater and Figure 37 for deep groundwater. The most noticeable difference for both the deep and shallow depths was between the pasture edge well position in transect A and the pasture edge wells located in transects B and C. Transect A pasture

edge groundwater had a much lower mean NO₃-N concentrations of 2.5 mg/L at the shallow depth and 1.6 mg/L at the deep depth compared to either transects B or C which had mean pasture edge concentrations that ranged from 8.9 mg/L to 10.5 mg/L for both the deep and shallow depths. This may be due to the direction of groundwater flow in Block 2 mentioned previously. This may have been due to a large swale that was located just upstream from transect C in Block 2. The swale ran directly from the pasture into the buffer and eventually the stream and was likely deep enough to cause larger groundwater delivery to transect C and transect B.

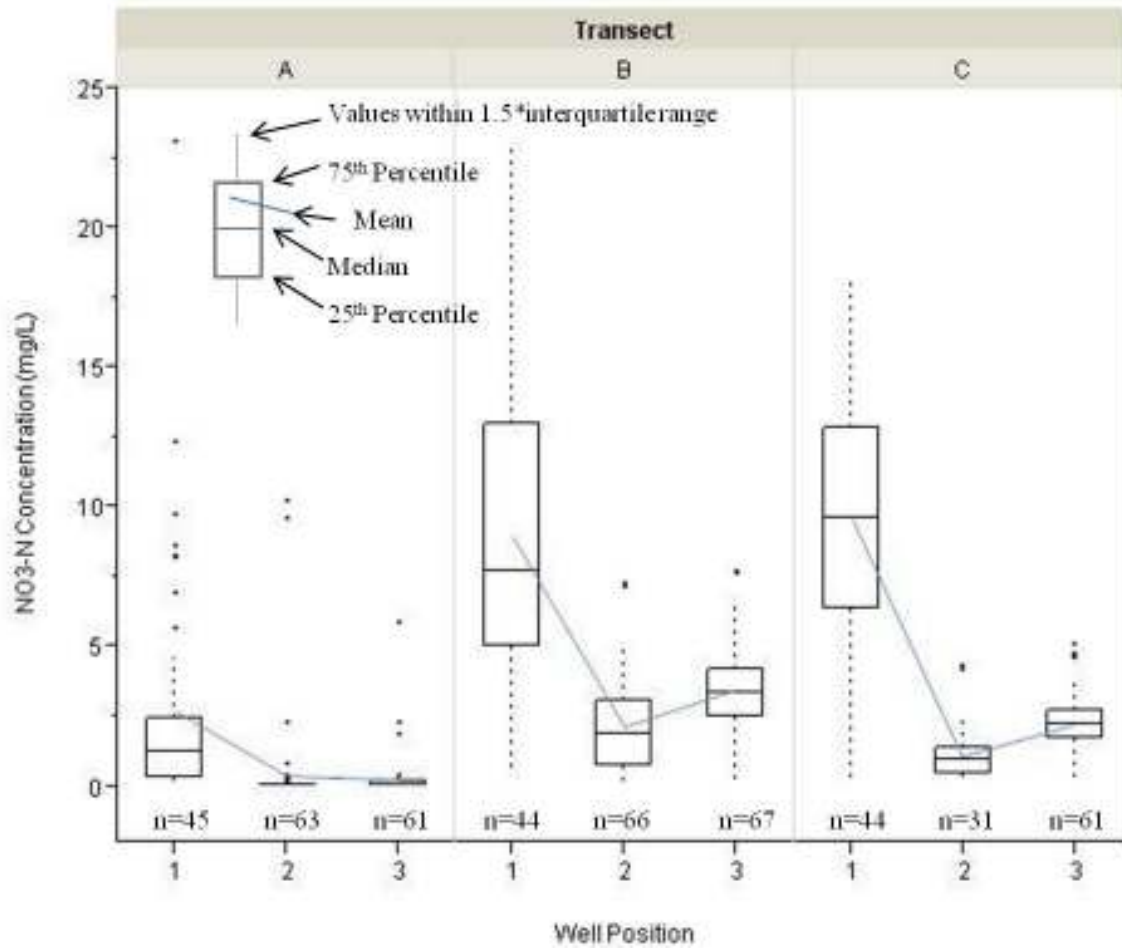


Figure 36. Block 2 shallow monitoring well NO₃-N concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend in means between different well positions.

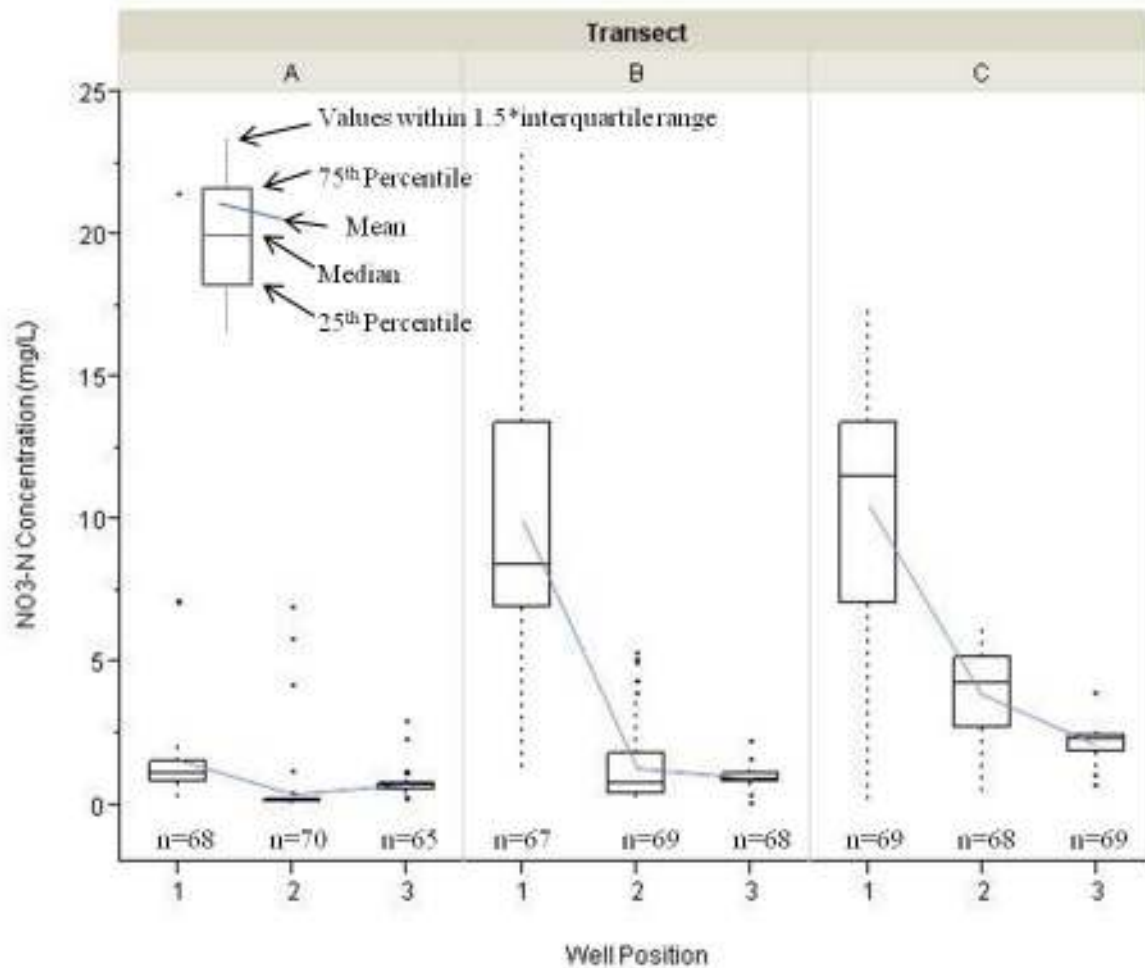


Figure 37. Block 2 deep monitoring well NO₃-N concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend in means between the different well positions.

Nitrate-nitrogen concentrations were also analyzed for any seasonal trends in incoming concentrations at the pasture edge. All groundwater samples in a season were averaged for each pasture edge groundwater depth. Deep and shallow groundwater NO₃-N concentrations were then graphed by season over the entire monitoring period as shown in

Figure 38. No strong seasonal trend could be identified, however, periods of slightly higher concentrations were generally found in the winter and spring of each year, such as the winter and spring of 2006 and spring of 2008.

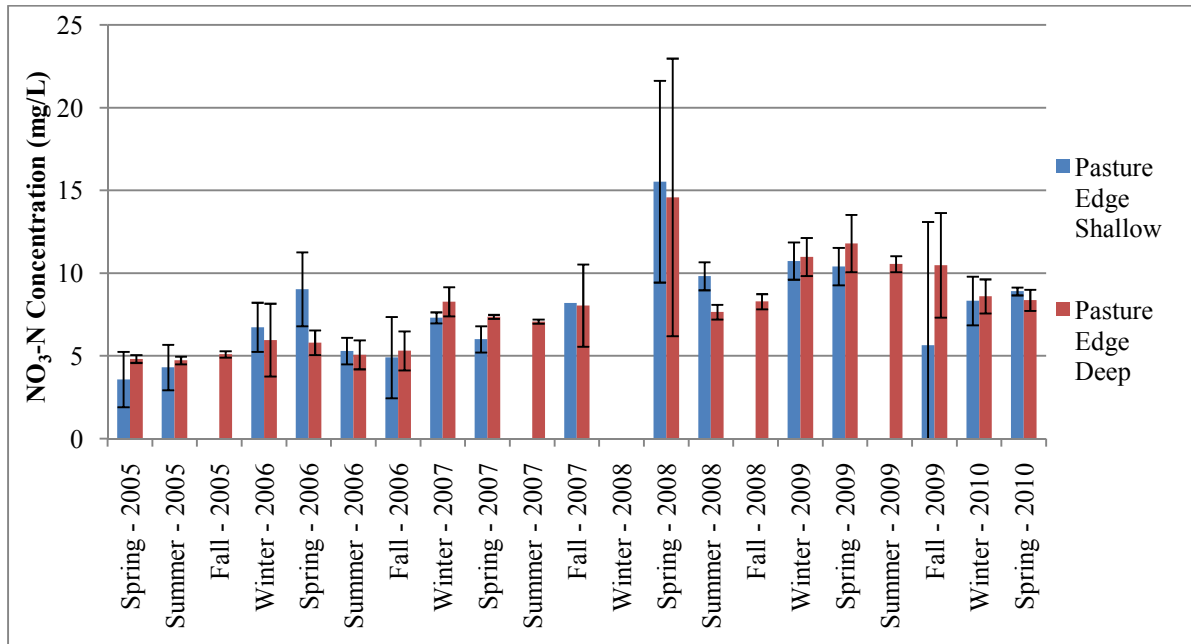


Figure 38. Block 2 mean NO₃-N seasonal concentrations over the monitoring period. Error bars represent standard deviations of individual seasonal mean concentrations.

Table 9 shows the yearly NO₃-N loads per hectare of contributed area calculated for deep and shallow groundwater over the monitoring period. It should be noted that the shallow and deep layers refer to approximately 1.8 m (6 ft) sections of groundwater in the upper aquifer from the top of the water table down to the saprolitic soil layer discussed in the soils section. Due to the decreases in NO₃-N concentration, the total combined load of deep and shallow groundwater decreased from pasture edge to stream edge in every monitoring year. Yearly total pasture edge NO₃-N loads ranged from 0.9 to 2.4 kg/ha/yr. A review of

relevant literature found these values were on the lower end of ranges reported by Line et al (2000) and Beulac and Reckhow (1982). Both of these studies reported NO_3^- load export ranges of 6-36 kg/ha/yr and approximately 2-30 kg/ha/yr respectively. Some of this discrepancy could be because these studies measured loads in streams at the outlet of the watershed rather than in groundwater like this study. Stream edge total loads were calculated to range between 0.2 and 0.4 kg/ha/yr. This corresponded to percent reductions in load between the pasture edge and stream edge wells of between 49% and 89% per year. A mean percent reduction of loads was calculated to be 75% or about 1.2 kg/ha/yr $\text{NO}_3\text{-N}$ removed by the buffer each year.

At the mid-buffer and stream edge loads were similar for shallow and deep wells for a majority of the monitoring period. At the pasture edge, a larger load was calculated for deep wells in all of the monitoring years. This was likely because the measured saturated hydraulic conductivity was higher in the deep layer than in the shallow layer (1.6 cm/hr and 0.8 cm/hr respectively), so that a larger volume of water was able to flow through the deep soil layer during the monitoring period. Yearly rainfall did not seem to affect the loads as observed in Block 1.

It should be noted that these loads calculations assume that no dilution of $\text{NO}_3\text{-N}$ concentrations was occurring in the monitoring block and that any reductions in concentrations was due to biological removal.

Table 9. Block 2 NO₃-N loads for deep 1.5 m (5 ft) and shallow 3.0 m depth groundwater

Year	Pasture Edge		Mid-Buffer		Stream Edge	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
2005	0.3	0.6	0.1	0.2	0.2	0.2
2006	0.8	1.1	0.1	0.3	0.2	0.2
2007	0.4	0.8	0.1	0.1	0.1	0.1
2008	1.0	1.4	0.0	0.3	0.1	0.1
2009	0.5	1.2	0.1	0.2	0.2	0.2
2010	0.6	0.8	0.1	0.1	0.2	0.1
Totals	3.5	5.7	0.5	1.2	1.0	1.0

Redox

Redox potentials were measured to determine if the anaerobic conditions associated with the denitrification process were occurring in the buffer at the depths water quality samples were collected and could support that observed reductions in NO₃-N concentrations were due to denitrification. Kralova et al (1992) and Bailey and Beauchamp (1973) found that denitrification was a major process at redox potentials below 200 mV. Bailey and Beauchamp also found that denitrification could occur at higher potentials, likely up to 400 mV, but that oxygen was simultaneously being utilized at potentials greater than 200 mV. Table 10 shows the percent of each year that each probe was below the water table, and the percent of sampling events each year that the mean redox potential was a) below +200 mV, indicating O₂ was likely depleted and NO₃⁻ was a primary electron acceptor, and b) below +350 mV, where both O₂ and NO₃⁻ were both being utilized as electron acceptors. It is

important to note that the reported redox potentials are just small points meant to estimate soil redox potentials for the entire buffer. Other locations in the buffer may have had either more positive or more negative potentials depending on localized conditions.

Table 10. Percent of each year Block 2 redox probes at the shallow (1.5 m depth) and deep (3.0 m depth) were below the water table and percent of sampling events each year that mean redox potentials were less than 200 mV or less than 350 mV.

Probe Location		2006 (n=6)	2007 (n=9)	2008 (n=7)	2009 (n=12)
Pasture Edge Shallow (1.5 m depth)	% saturated*	54%	32%	25%	27%
	<200mV	17%	33%	43%	42%
	<350mV	100%	100%	100%	92%
Pasture Edge Deep (3.0 m depth)	% saturated*	100%	73%	86%	79%
	<200mV	100%	100%	86%	83%
	<350mV	100%	100%	100%	100%
Mid-Buffer Shallow (1.5 m depth)	% saturated*	100%	100%	100%	100%
	<200mV	67%	11%	14%	0%
	<350mV	100%	67%	29%	17%
Mid-Buffer Deep (3.0 m depth)	% saturated*	100%	100%	100%	100%
	<200mV	100%	100%	100%	100%
	<350mV	100%	100%	100%	100%
Stream Edge Shallow (1.5 m depth)	% saturated*	100%	100%	100%	100%
	<200mV	0%	11%	0%	0%
	<350mV	17%	33%	29%	33%
Stream Edge Deep (3.0 m depth)	% saturated*	100%	100%	100%	100%
	<200mV	50%	100%	100%	92%
	<350mV	100%	100%	100%	100%

*Note: % saturated represents percentage of days soil surrounding the redox probe was saturated

Figure 39 shows the redox potential values for the shallow and deep redox probes at the pasture edge, as well as the pasture edge water table elevations for the year 2009. Other

years of the monitoring period can be found in Appendix B. Probe elevations were approximately 59.5 m (195 ft) and 58.3 m (191 ft) for shallow and deep probes respectively.

The water table was above the shallow probes at the pasture edge for brief periods in February, March, November and December when the water table was at its highest elevations. In response, mean redox potentials were lower during these periods when compared with the drier periods of the year. This was true for all of the years that were monitored. Table 10 shows that mean potentials were only below the +200 mV threshold for a maximum of 43% of the monitoring events in a year, which occurred in 2008. However, mean potentials were below the +350 mV threshold for nearly the entire monitoring period, with only 1 sampling event in 2009 not below the threshold.

The water table was above the deep probes for the majority of each year. Redox potentials at the beginning of each year tended to begin at a more positive value and then gradually decrease through the year until some period in October or November when potentials began to increase. October and November were usually when the water table was at its lowest elevation and when the deep probe was above the water table for the longest period of time. This is evident in Figure 39 in November, when redox readings increased rapidly when the water table fell below the elevation of the probes. The trend was similar to what was found for Block 1 pasture edge redox and was true for all of the years monitored. In Block 2, the mean redox potentials were always below the +350 mV threshold. They were

below the +200 mV threshold for 79% of 2009 and were below the threshold for a majority of each of the other monitoring years.

This indicated that the potential for denitrification was high at the pasture edge at both the shallow 1.5 m (5 ft) and the deep 3 m (10 ft) groundwater depths. The deep depth was thought to have more potential for denitrification because the mean redox potentials were lower there, likely because the soil at these depths was more frequently saturated.

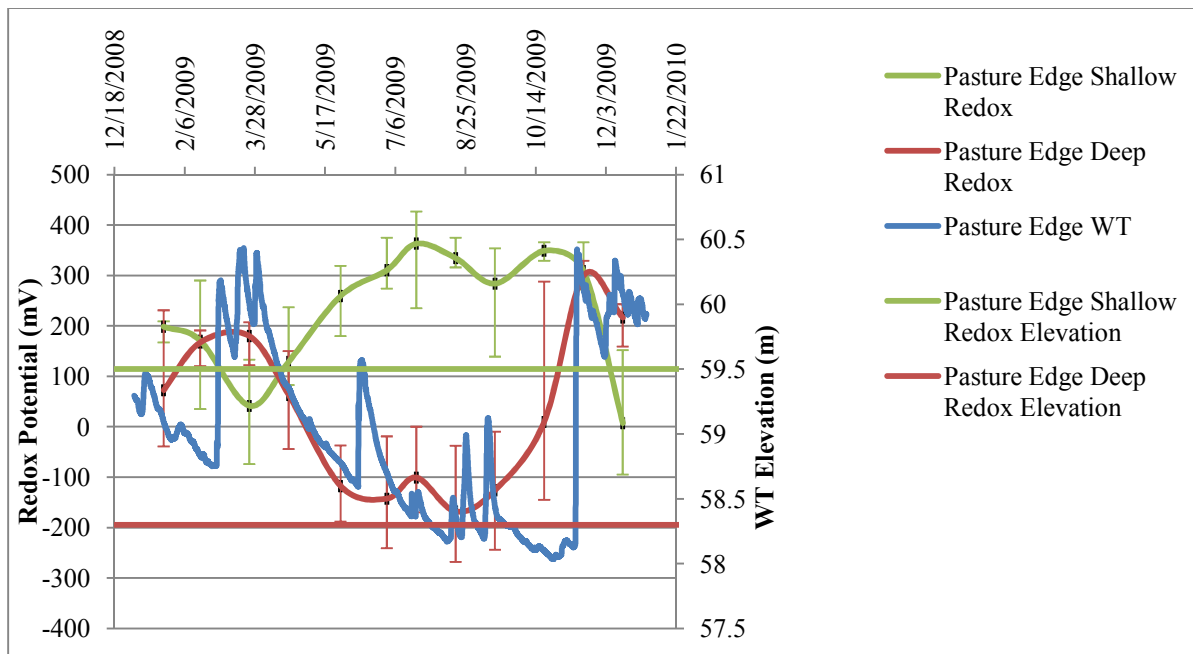


Figure 39. Block 2 mean pasture edge redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Figure 40 shows mid-buffer mean redox potentials and water table elevations for 2009. A rough estimate of the water table was used in the figure because no water table loggers were installed at the mid-buffer position. The estimate was obtained by adding the

difference in ground elevation between the mid-buffer and stream edge well positions (about 0.5 m (1.6 ft)) to the stream edge water table elevations that were logged in the monitoring block. This was likely a conservative estimate of the actual water table at the mid-buffer because the stream lowered the water table at the stream edge. Mid-buffer shallow redox probes were placed at an elevation of 58.5 m (192 ft) and were inundated by the water table for the entire monitoring year. In all monitoring years, the mean shallow probe redox potentials slowly increased as the water table at the site fell to lower elevations in October and November, similar to the shallow probe trend found at the pasture edge. However, shallow redox potential means were never below the +200 mV threshold in 2009 and were never below the threshold more than 14% of the sampling events in the other years, except in 2006, when the water table was at its highest elevations throughout the year and was below the +200 mV threshold for 67% of the sampling events. In 2008 and 2009 the mean potentials were rarely below the +350 mV threshold (less than 30% of sampling events) and in 2007 potentials were only below the threshold for 67% of the sampling events. Only in 2006 were all of the mean potentials below the +350 mV threshold.

Mid-buffer deep probes were placed at an elevation of 57.0 m (187 ft) and were below the elevation of the water table in a majority of all the monitoring years. Redox potentials tended to be low with only small changes throughout each year. The redox potential means were below the +200mV threshold for every sampling event in the monitoring period. This indicated that the potential for denitrification was very high at this

location in the buffer and that the 3.0 m deep groundwater depth had a higher potential than the 1.5 m (5 ft) depth groundwater.

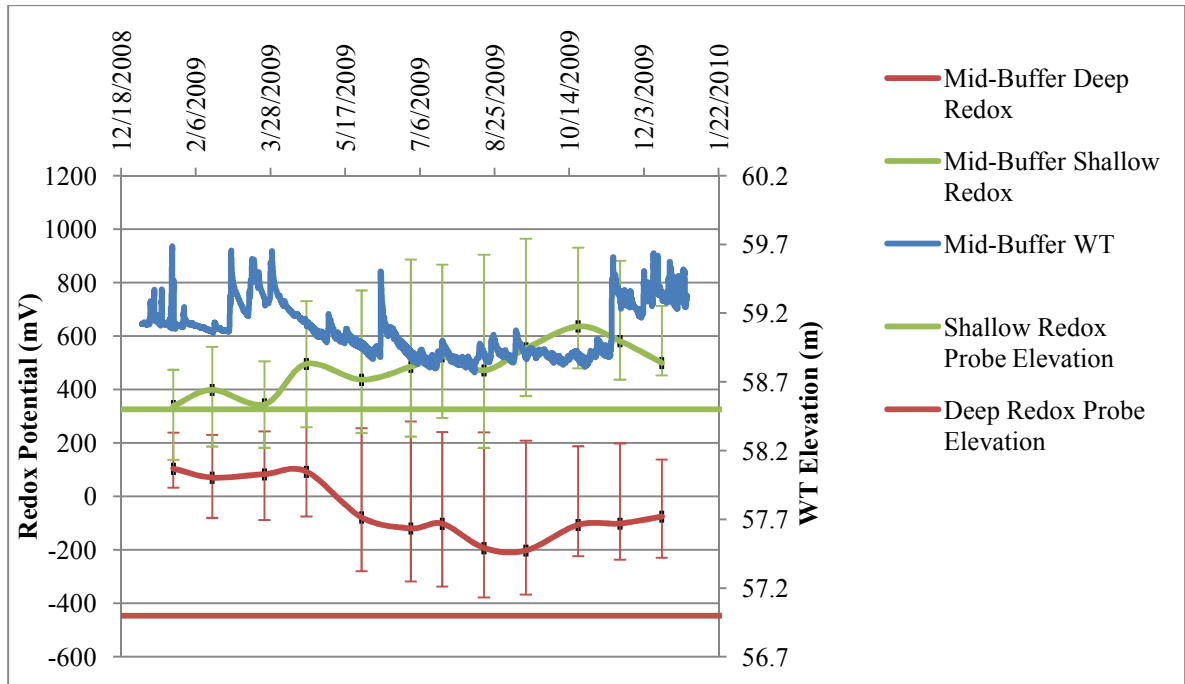


Figure 40. Block 2 mean mid-buffer redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Figure 41 shows the redox potentials and water table elevations for the stream edge groundwater in 2009. Stream edge shallow and deep redox probes were placed at elevations of 58.0 m (190 ft) and 56.7m (186 ft) respectively and were below the elevation of the water table for a majority of the monitoring period. However, relatively high redox values were recorded for the shallow redox probes with most of the years never falling below the +200 mV threshold and only falling below the +350 mV threshold for a maximum of 33% of

yearly sampling events despite soils around the probes being saturated in all of the years. All of the individual electrodes (a total of 5) in the probe cluster had fairly high potential readings compared to the other inundated probes, and one individual electrode showed consistent reading above +500 mV. Even after this individual electrode was removed from calculating the mean, only 2 of the 38 sampling events had a mean potential of less than +200 mV. This was unexpected and may be due to a possible malfunction or a leak around the well that was described at the mid-buffer deep probe in Block 1. Another possibility O₂ rich water from the stream interacted with the probe during periods when groundwater may have been moving from the stream to the buffer.

Stream edge redox potentials at the deep 3.0 m (10 ft) depth lacked the decreasing trend of potentials from the winter and spring to the autumn months found at the pasture edge but were a more consistent potential throughout the year. All of the mean potentials fell between +55 mV and +210 mV, the smallest range of any of the probes in the study. As shown in Table 10, the mean potentials were below +200 mV threshold for a majority of the recording events in the monitoring period.

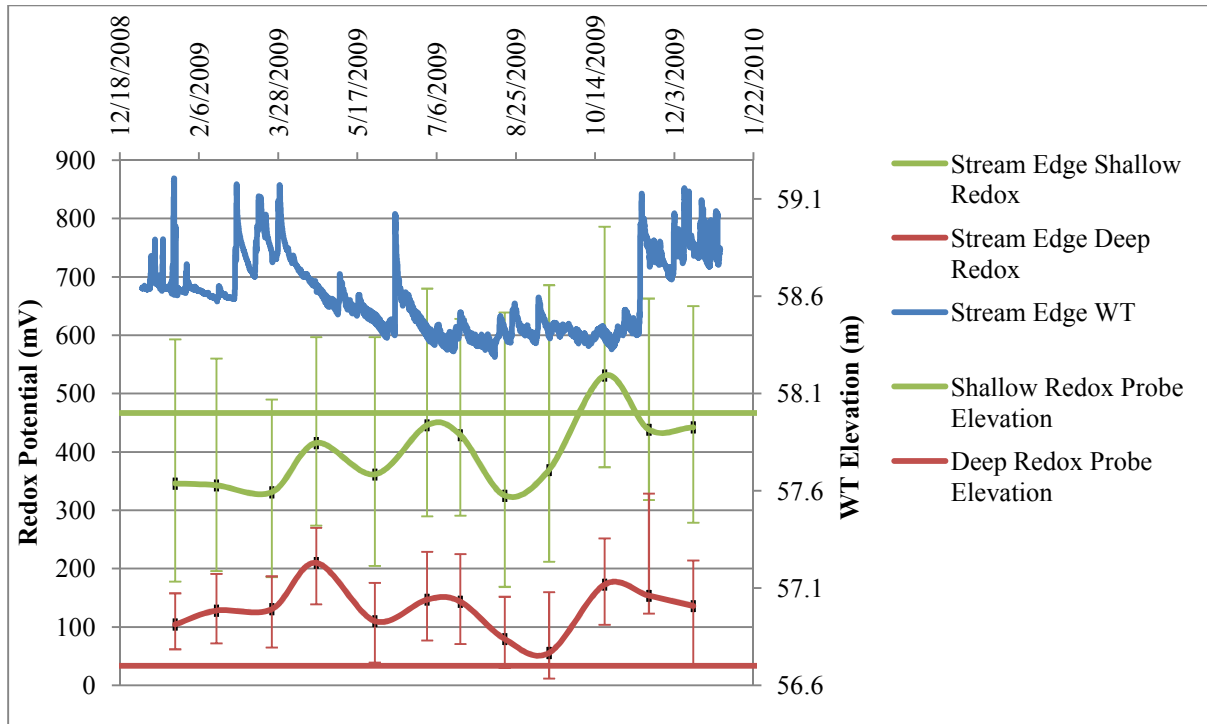


Figure 41. Block 2 mean stream edge redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

All mean deep soil redox potentials were below the +200 mV threshold for a majority of the sampling events in Block 2 which suggested that, theoretically, redox conditions were ideal for denitrification to occur at this depth. It was rarer to find redox potentials at the shallow depth to be below the +200 mV threshold or the +350 mV threshold, which indicated that the potential for denitrification may have been lower at the shallow depth.

Groundwater Quality – Dissolved Organic Carbon (DOC)

To assess soil carbon availability for denitrification, DOC was sampled at the site from August 2008 to February 2010 on a bi-monthly basis. Figure 42 is a boxplot of Block 2 DOC concentrations and shows that median groundwater concentrations were similar throughout the site, ranging from 1.3 mg/L to 3.2 mg/L. Mean groundwater concentrations had a larger deviation, ranging from 3.1 mg/L to 7.2 mg/L. There was found to be no difference between groundwater at different well positions for deep and shallow depths (values ranged from $p = 0.0692$ to $p = 0.8201$) except between pasture edge shallow and stream edge shallow groundwater which was significantly different ($p = 0.0436$). Figure 43 shows the seasonal concentrations of DOC, but a seasonal trend could not be detected during the 18 month collection period. The figure does show that concentrations were highest during the summer of 2008 much lower during the following time periods and then slightly elevated again during the fall of 2009 and winter of 2010. The figure also shows that that DOC was evenly distributed in groundwater between the different areas of the buffer.

Mean DOC concentrations in Block 2 were on the lower side of the range that denitrification has been shown to occur by other researchers. Obenhuber and Lowrance (1991) found that a small amount of denitrification could occur with DOC concentrations of about 4 mg/L in laboratory microcosms and the rate drastically increased when DOC concentration increased to 10 mg/L. Similarly, Starr and Gillham (1993) found significant denitrification occurred in a sandy aquifer with DOC concentrations from about 5 mg/L to 10 mg/L while almost no denitrification could be identified in a sandy aquifer with 2 mg/L to 3

mg/L concentrations of DOC. While a majority of Block 2 DOC concentrations were on the lower side of the denitrification range, samples at all well positions were frequently measured with much higher concentrations, in some cases above 15 mg/L. This seemed to suggest that DOC concentrations in the buffer were sufficient for some denitrification to occur but the process was likely limited by carbon for portions of the year.

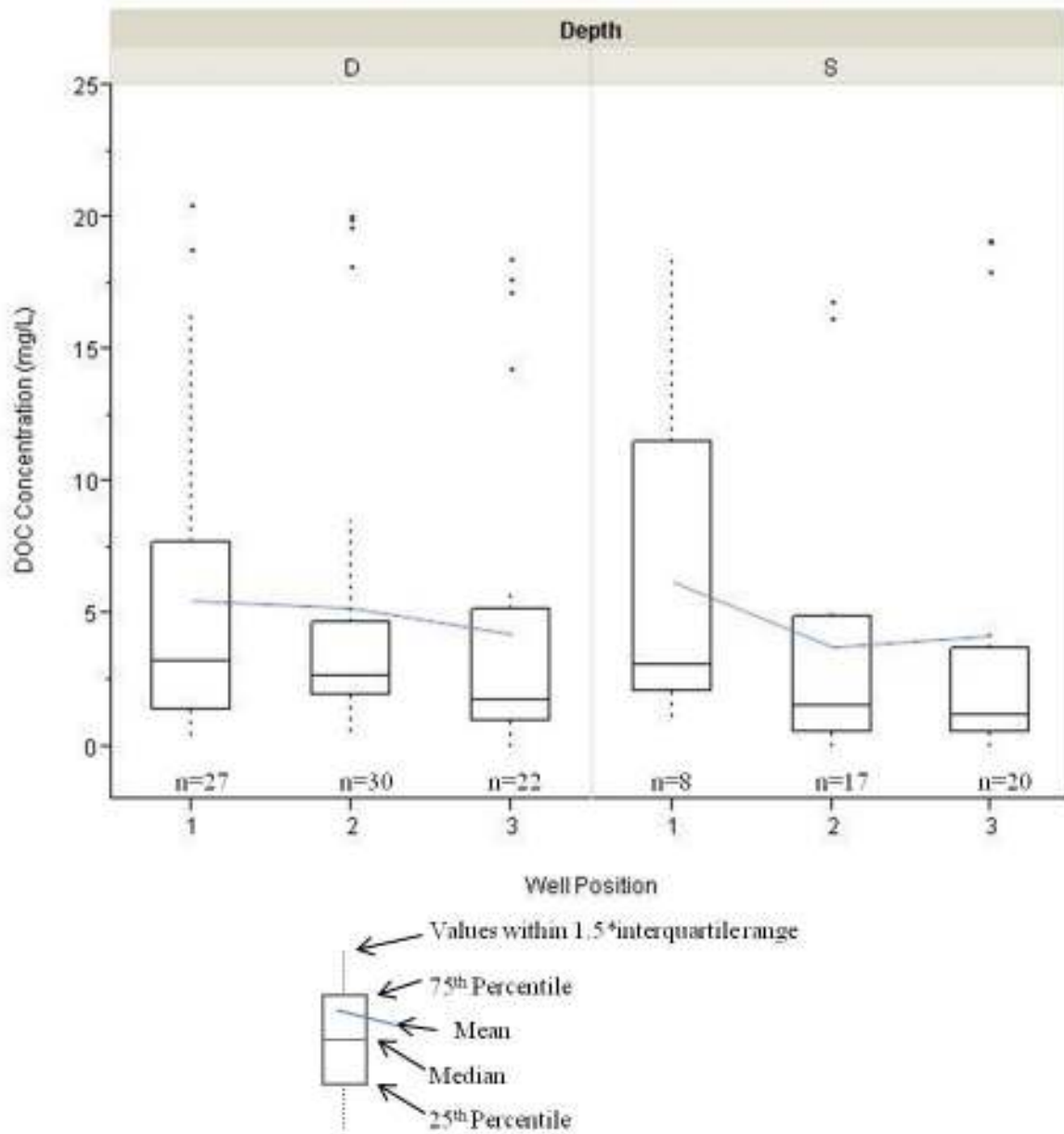


Figure 42. Block 2 DOC samples in deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position.

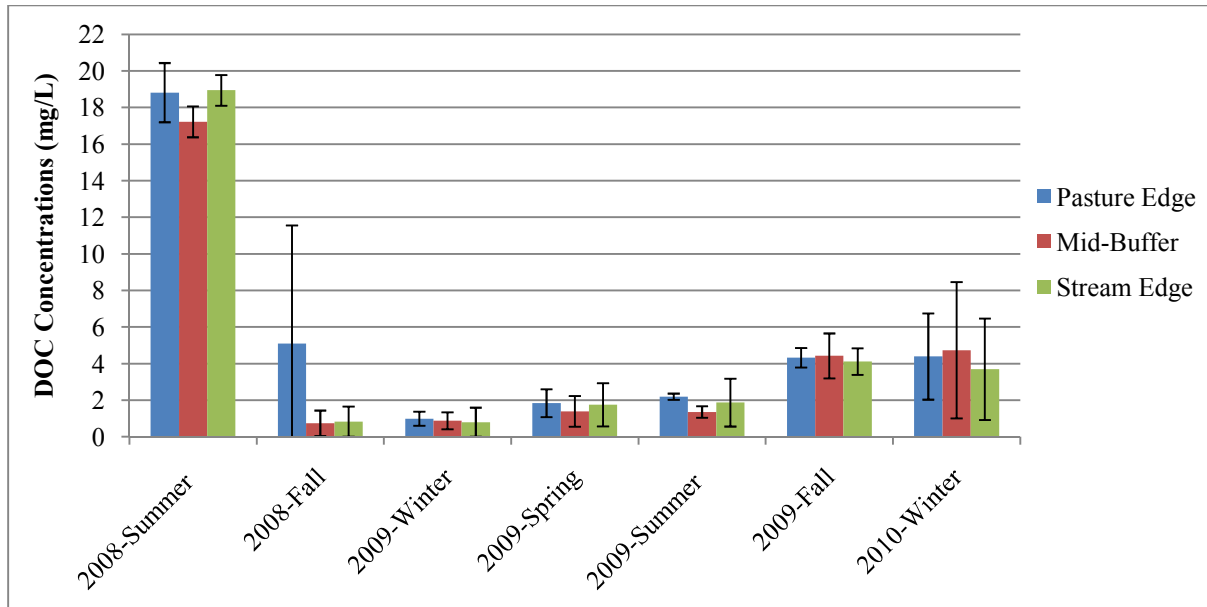


Figure 43. Block 2 mean seasonal DOC concentrations. Error bars represent the standard deviation of the value.

Redox potentials and groundwater DOC concentrations in Block 2 both indicated that the conditions required for denitrification to occur were present in the monitoring period. Reductions in $\text{NO}_3\text{-N}$ concentrations between the pasture edge and stream edge groundwater could potentially be attributed to denitrification.

Groundwater Quality – Nitrate/Chloride Ratios

Chloride concentrations were used to normalize $\text{NO}_3\text{-N}$ concentrations to determine if NO_3^- was actually being removed from the buffer, via vegetation uptake or denitrification, or if concentrations were being diluted by NO_3^- poor groundwater mixing with the surficial aquifer. The source of Cl^- in groundwater that was entering the buffer was the same as the source of $\text{NO}_3\text{-N}$, poultry litter that was broadcast on the upland pasture as fertilizer. $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios that decrease from the pasture edge to the stream edge are usually associated with

NO₃-N removal in the buffer, assuming a nearly constant Cl⁻ concentration. Ratios that do not change from the pasture edge to the stream edge are indicative of no NO₃-N removal, only dilution by a NO₃-N and Cl⁻ poor groundwater source. Ratios that increase across the buffer might indicate that either NO₃-N was increasing across the buffer while Cl⁻ was stable or NO₃-N concentrations were stable while Cl⁻ concentrations were decreasing. Both of these scenarios would require a source of NO₃-N originating inside the buffer.

Figure 44 shows overall NO₃-N/Cl⁻ ratios decreased from pasture edge to stream edge in Block 2. Ratios did increase slightly between the mid-buffer and stream edge groundwater. However, the overall mean percent reductions between the pasture edge and stream edge were 43% and 37% for the shallow 1.5 m depth and deep 3.0 m depth groundwater respectively.

Figure 45 shows that NO₃-N/Cl⁻ ratios decreased from pasture edge to stream edge in Block 2 shallow (1.5 m depth) groundwater. Ratios did increase between the shallow mid-buffer well position and stream edge well position in transects B and C, however, stream edge ratios were still below those calculated for the pasture edge. Differences between all well position means were significant at the shallow depth and the mean percent reductions between the pasture edge and stream edge for transect A, B, and C were 86%, 22%, and 50% respectively.

Figure 46 shows that NO₃-N/Cl⁻ ratios in the deep (3.0 m depth) groundwater decreased in transects B and C between the pasture edge and stream edge but did not in

transect A where ratios increased. Differences between all well position means were also significant at the deep depth except between the pasture edge (Well Position 1) and the stream edge (Well Position 3) ($p = 0.4882$). The percent difference between the pasture edge and stream edge increased by 123% in transect A, but decreased by 68% and 40% in transects B and C respectively.

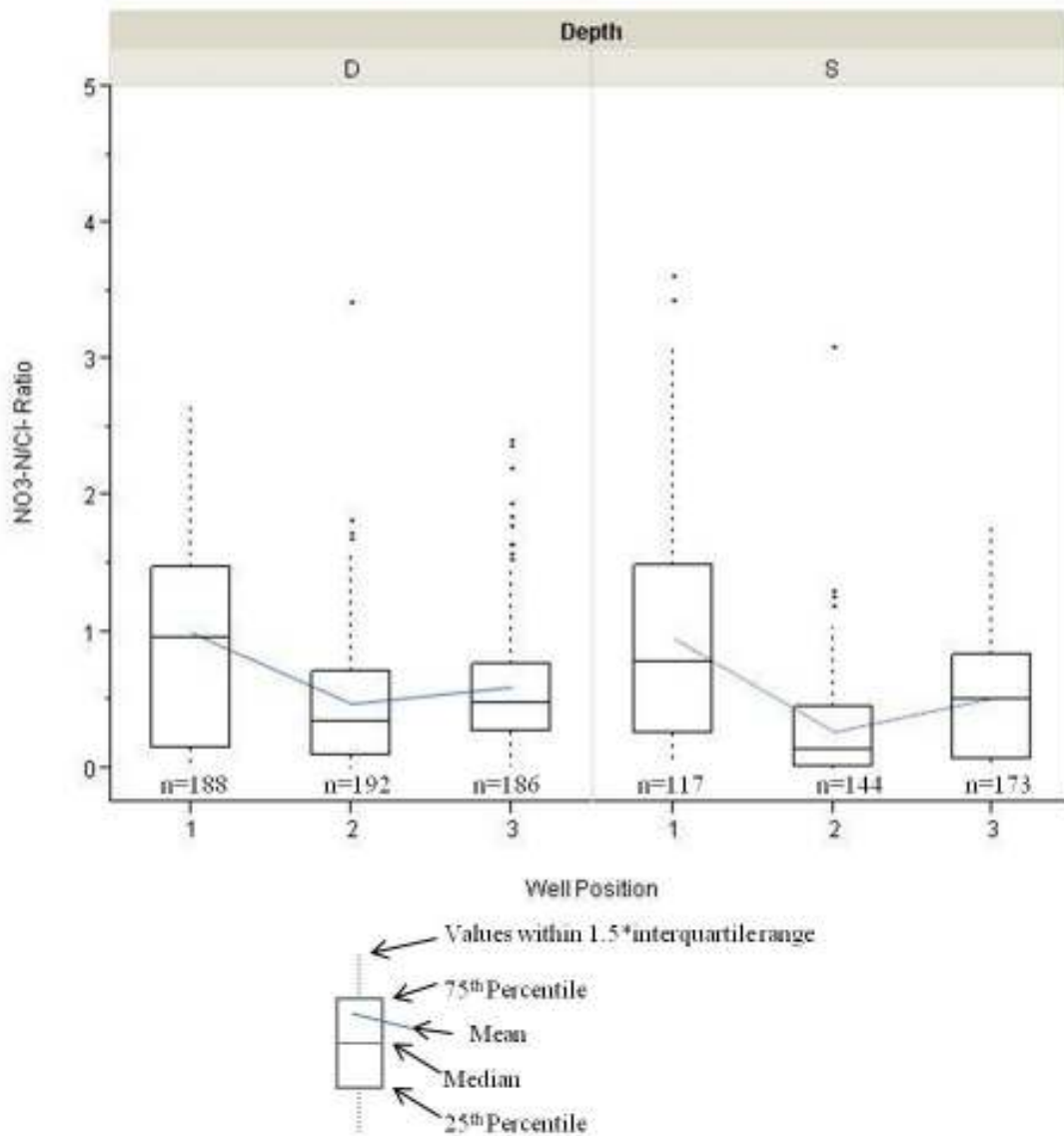


Figure 44. Block 2 shallow (1.5 m depth) and deep (3.0 m depth) groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend between means at each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 15.4

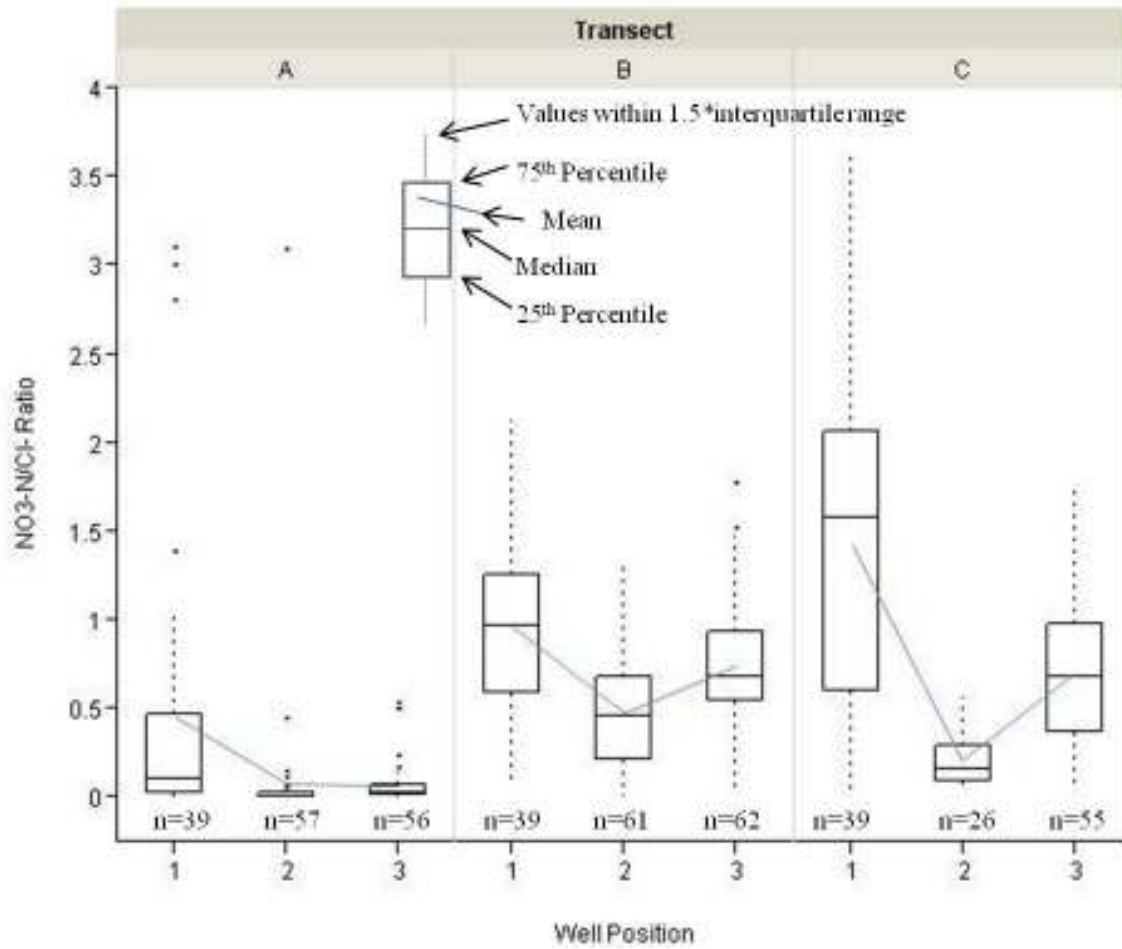


Figure 45. Block 2 shallow (1.5 m depth) groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at different well positions.

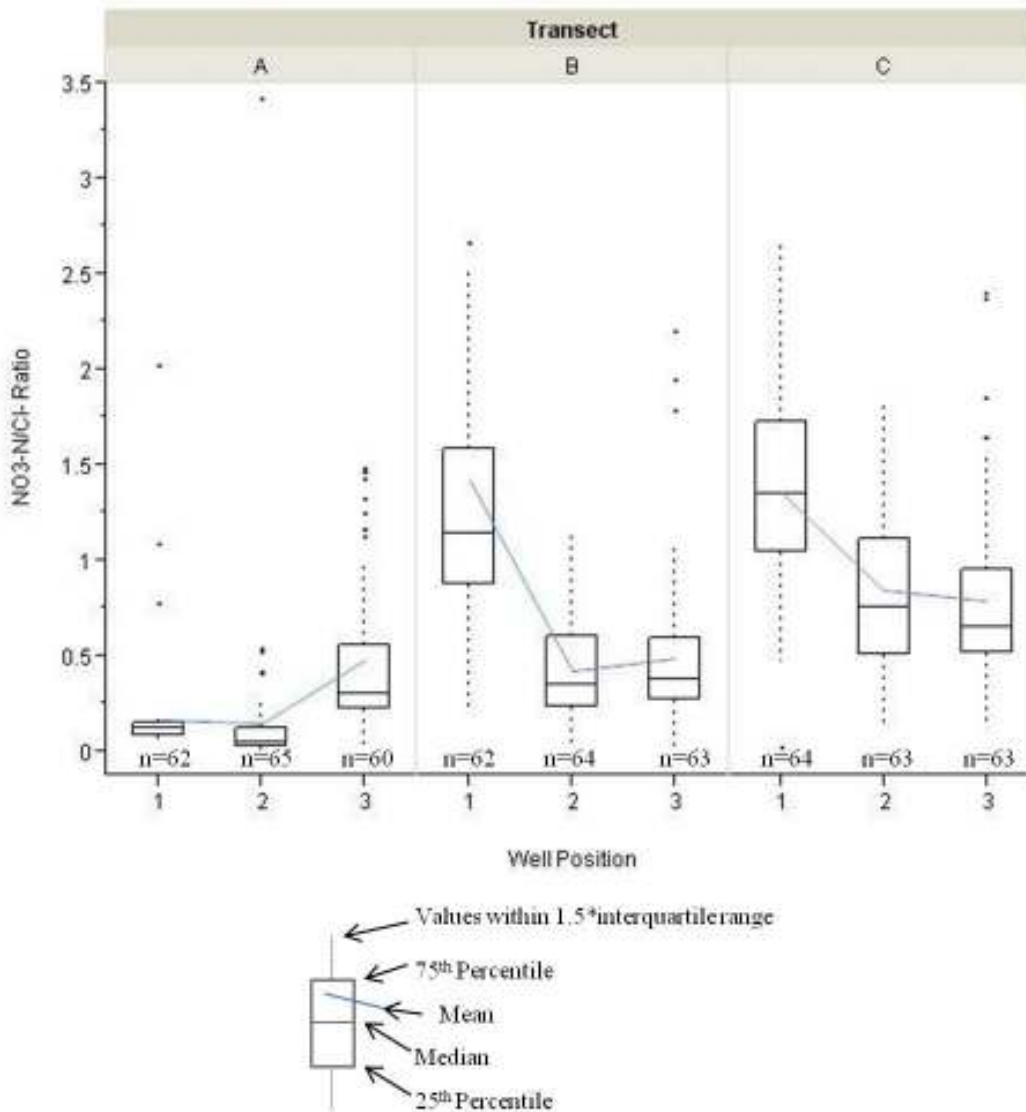


Figure 46. Block 1 deep 3.0 m (10 ft) depth groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at different well positions. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 15.4

Groundwater Quality – Chloride (Cl⁻)

If Cl⁻ concentrations were very similar among all well positions across the monitoring block, indicating that very little dilution due to groundwater mixing was occurring, then the NO₃-N/Cl⁻ ratios discussed above would indicate that NO₃-N was being removed by the buffer,

However, NO₃-N/Cl⁻ ratios increased between several different well positions in Block 2; for instance at the 3.0 m (10 ft) groundwater depth in transect A ratios were the highest at the stream edge and in the shallow 1.5 m (5 ft) depth ratios in transects B and C increased between the mid-buffer and stream edge groundwater. This could imply that Cl⁻ concentrations decreased at a faster rate than NO₃-N concentrations. For a clearer picture of how Cl⁻ concentrations may have been affecting the NO₃-N/Cl⁻ ratios, Cl⁻ was analyzed to see at what level it fluctuated in concentration in the buffer.

Figure 47 is a boxplot of shallow and deep Cl⁻ concentrations in Block 2 at different well positions. Shallow and deep groundwater shows highest Cl⁻ concentration at the pasture edge well position and lower concentrations through the mid-buffer and stream edge well positions. At the deep 3.0 m (10 ft) depth, the pasture edge well position was found to be significantly different from both mid-buffer and stream edge well positions. No significant difference was found between the mid-buffer groundwater concentrations and the stream edge groundwater concentrations ($p = 0.1674$). This seemed to indicate that significant amounts groundwater mixing with a Cl⁻ poor aquifer was causing dilution of concentrations between the pasture edge and mid-buffer groundwater. Some of the reductions in NO₃-N

between the pasture edge groundwater and mid-buffer groundwater were also likely to be due to dilution of concentrations. A Cl^- percent reduction of 66% was calculated between the pasture edge deep groundwater and the stream edge deep groundwater.

There was no statistically significant difference in Cl^- concentrations between the pasture edge shallow well position and the mid-buffer shallow well position ($p = 0.1916$), the pasture edge shallow well position and the stream edge shallow well position ($p = 0.1869$), or the mid-buffer shallow well position and stream edge shallow well position ($p = 0.1783$). Statistically, this suggested that groundwater mixing and dilution of concentrations did not have a significant effect on the shallow layer, but the percent reduction in mean concentrations between the pasture edge and the stream edge was calculated to be 64%, similar to the reduction observed in deep wells when the difference between the pasture edge deep groundwater and stream edge deep groundwater which were found to be significantly different.

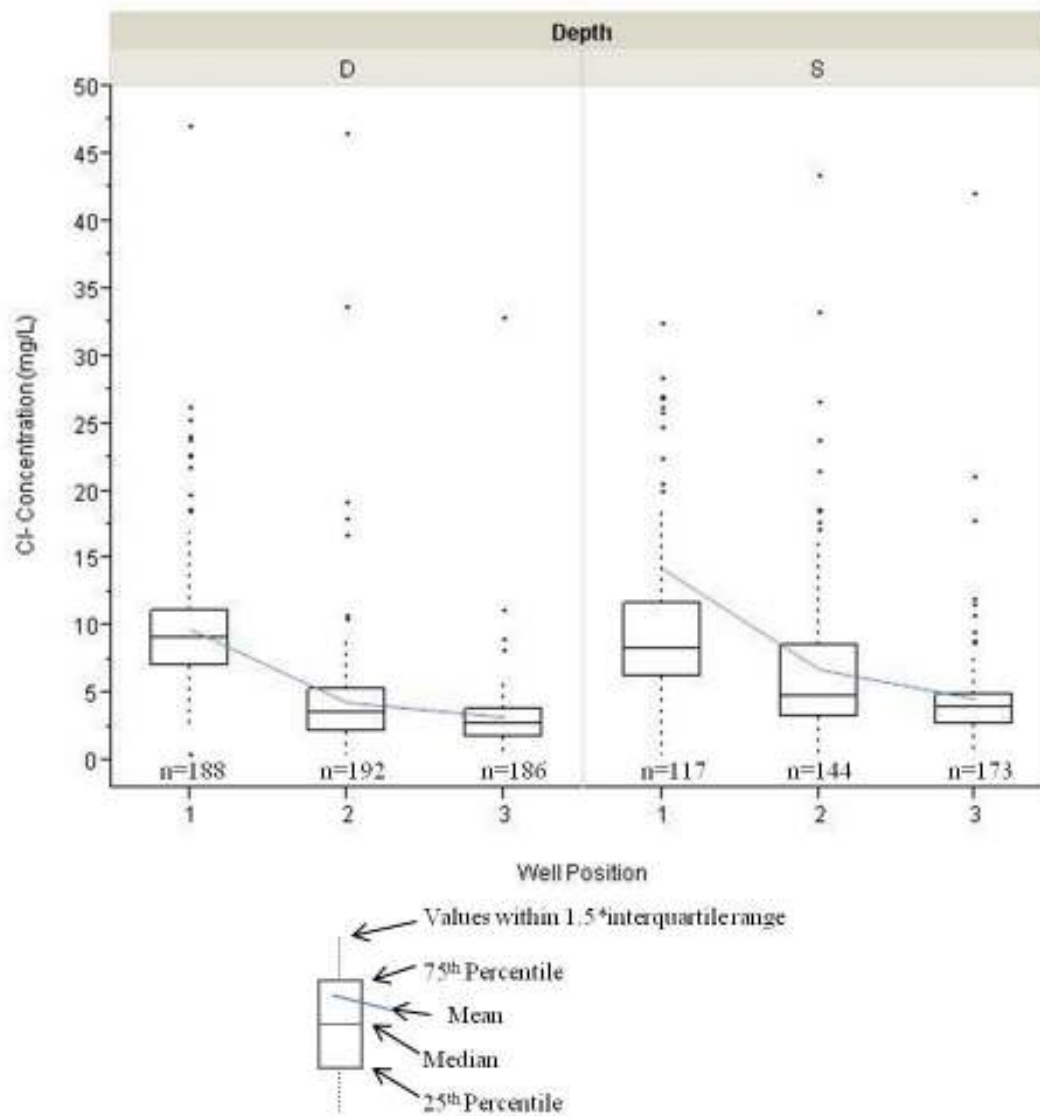


Figure 47. Block 2 deep (D) and shallow (S) monitoring well Cl⁻ concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at different well positions. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 72.5 mg/L, PES - 400.0 mg/L, 154.0 mg/L, SES - 55.8 mg/L.

Chloride concentrations were further split by transect to determine if groundwater mixing could be pinpointed to specific areas of the buffer. Figure 48 shows the shallow Cl^- concentrations at each well position separated by transect. Chloride concentrations are relatively similar in pasture edge and mid-buffer wells in transects A and C. The concentrations do decrease between the mid-buffer and stream edge well positions in these two transects. In transect B there was a decrease between pasture edge groundwater and mid-buffer groundwater. As noted earlier the differences between the well positions were not statistically significant.

Figure 49 shows the deep well Cl^- concentrations separated by transect. All three transects show a similar decrease in concentrations between the pasture edge and the mid-buffer well positions that was found to be statistically significant. The groundwater mixing and dilution of concentrations seemed to have occurred in all transects.

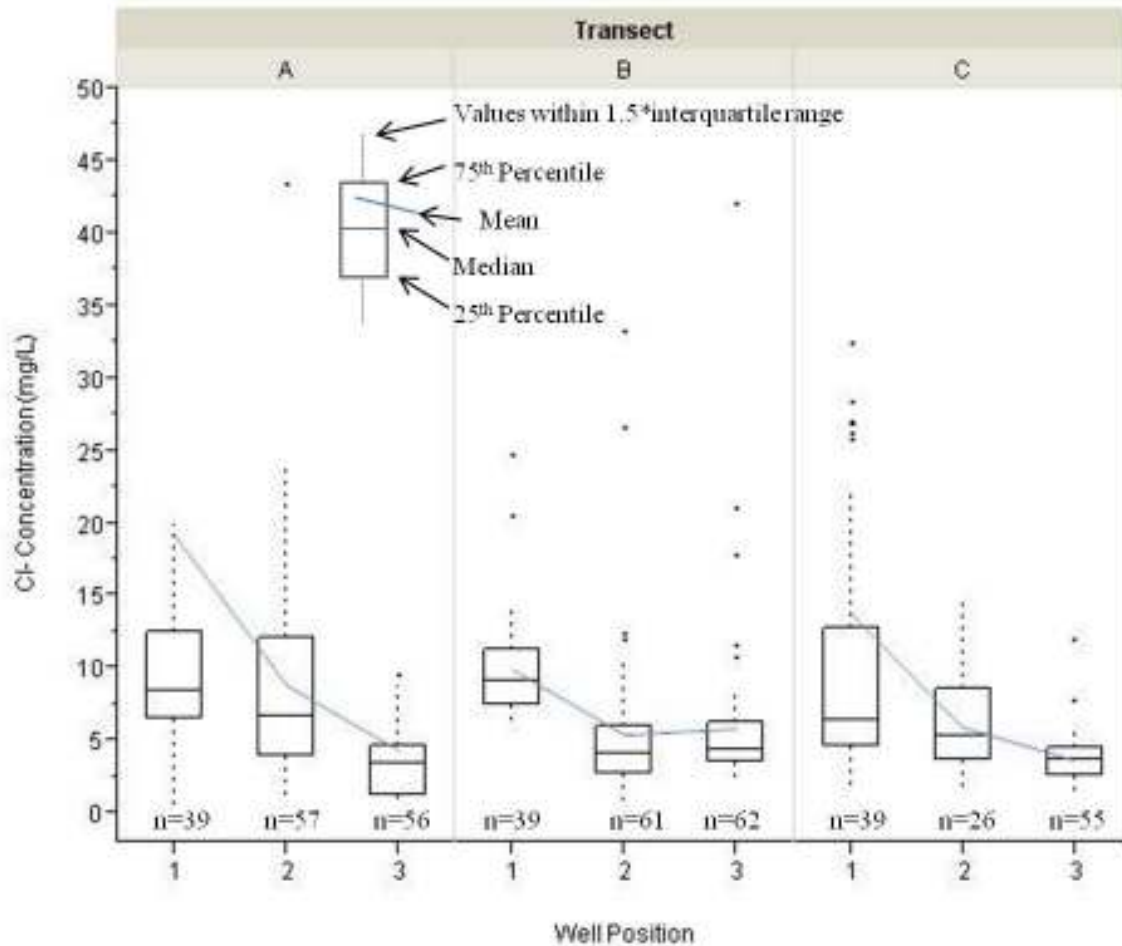


Figure 48. Block 2 shallow monitoring well Cl⁻ concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at different well positions. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PES - 400 mg/L, 154.0 mg/L, SES - 55.8 mg/L.

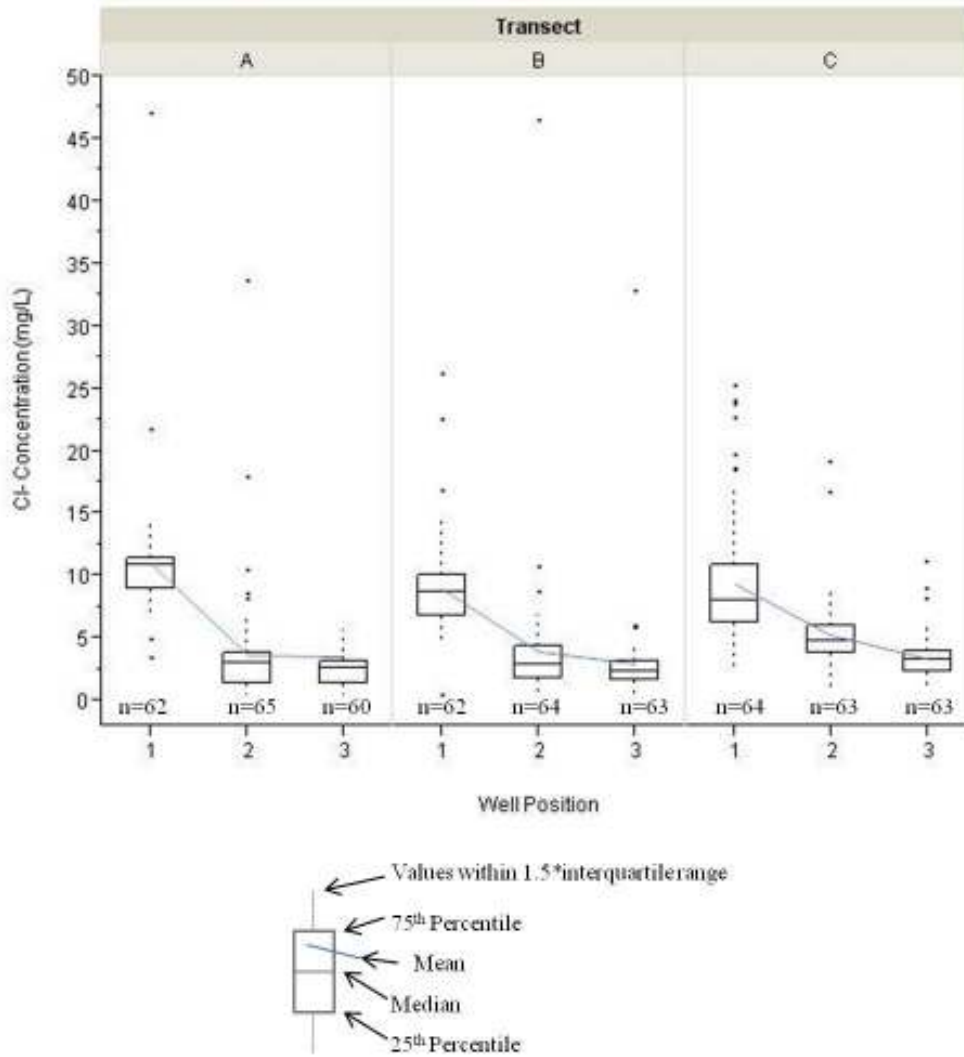


Figure 49. Block 2 deep monitoring Cl⁻ concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at different well positions. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: SED - 72.5 mg/L.

While decreasing NO₃-N/Cl⁻ ratios indicated that NO₃⁻ removal occurred, decreasing Cl⁻ concentrations indicated that dilution also occurred. More investigation was needed so

that a better conclusion could be drawn from the data. The mean of groundwater NO₃-N and Cl⁻ concentrations for all pasture edge and stream edge 1.5 m (5 ft) and 3.0 m (10 ft) depth samples were calculated for each sampling date. The means were then plotted throughout the entire monitoring period as shown in Figure 50 for the shallow 1.5 m (5 ft) groundwater depth and Figure 51 for the deep 3.0 m (10 ft) groundwater depth.

Figure 50 shows that NO₃-N concentrations were higher at the pasture edge than the stream edge throughout the entire monitoring period. 41 of the 43 paired samples decreased in concentration between the pasture edge and stream edge groundwater at the shallow 1.5 m (5 ft) depth. About half of the samples (23 of the 43 sample pairs) decreased by more than 5 mg/L but only 2 of these samples decreased by more than 10 mg/L. The mean percent reduction between the pasture edge and stream edge groundwater at the 1.5 m (5 ft) depth was 56% and the median difference was 69%. The largest reduction was 95% and occurred on 5/13/2008. Concentrations at the pasture edge and stream edge were higher on 4/6/2005 and 3/15/2009, but increased by less than 1.5 mg/L.

The differences in Cl⁻ concentrations between the pasture edge and stream edge groundwater at the 1.5 m (5 ft) depth was very similar to the decreases found in NO₃-N concentrations above. 41 of the 43 paired samples decreased in Cl⁻ concentrations between the pasture edge and stream edge groundwater at the 1.5 m (5 ft) depth. 18 of the 43 paired samples decreased by more than 5 mg/L and 6 of the 43 samples decreased by more than 10 mg/L. The mean percent reduction between the pasture edge and stream edge groundwater at

the 1.5 m (5 ft) depth was 49% and the median reduction was 51%. The largest percent reduction in Cl⁻ Concentrations between the pasture edge and stream edge was 85% on 8/10/2006. Concentrations at the stream edge were higher only on 4/6/2005 and 2/18/2010, again both by less than 1.5 mg/L.

Overall Cl⁻ concentrations decreased in Block 2 shallow groundwater indicating that dilution by groundwater mixing with a Cl⁻ and NO₃-N poor groundwater source was a major process in this monitoring block at the shallow 1.5 m (5ft) depth. Mean concentrations in the groundwater at 7.6 m (25 ft) below the ground surface at the stream edge were 0.8 mg/L and 3.0 mg/L for NO₃-N and Cl⁻ respectively and may have been a major source of dilution. Different concentrations of NO₃-N and Cl⁻ in the dilution source could have caused different rates of reductions in the concentrations in the surficial aquifer. However for this analysis dilution was assumed to have the same effect on both NO₃-N and Cl⁻ concentrations in the upper aquifer where the shallow (1.5 m (5 ft) depth) and deep (3.0 m (10 ft) depth) groundwater was located. The greater change in NO₃-N concentrations between the pasture edge groundwater and stream edge groundwater when compared to the change in Cl⁻ concentrations indicated that biological removal in excess of dilution could have occurred in the block. By subtracting the percent change in Cl⁻ concentrations from the percent change in NO₃-N concentrations the role of biological removal in the buffer could be estimated as shown in Equation 10:

$$\Delta NO_3 - N\% - \Delta Cl^- \% = \Delta NO_3 - N\% \textit{ due to biological removal} \quad [10]$$

This analysis was similar to one performed by Schoonover and Williard (2003). Table 21 in Appendix D shows the values that were calculated for each sampling date in the monitoring period. It should be noted that these estimations of biological removal represent the maximum removal that could be expected in the monitoring block, actual removals may have been lower.

The mean difference between the percent reduction in $\text{NO}_3\text{-N}$ concentrations and the percent reduction in Cl^- concentrations between the pasture edge shallow groundwater and stream edge shallow groundwater was 20% and the median difference was 16%. This indicated that $\text{NO}_3\text{-N}$ concentrations decreased between the pasture edge and the stream edge on average at a magnitude that exceeded that of Cl^- , but less than the overall reduction estimate of 70%. The largest difference in reductions was 82% which occurred on 2/18/2010.

Figure 50 shows that near the end of 2007 Cl^- concentrations at the stream edge may have been higher than in years previous. Stream edge concentrations also seemed to more closely track with Cl^- concentrations at the pasture edge. As was done in Block 1 the data was split into a pre-2008 and post-2008 sets and analysed in the same manner that the entire data set was analyzed. Similar to Block 1, the post-2008 data had a larger biological uptake of 41% reduction in $\text{NO}_3\text{-N}$ concentrations while the pre-2008 data group had a biological removal of only 6% $\text{NO}_3\text{-N}$ concentrations.

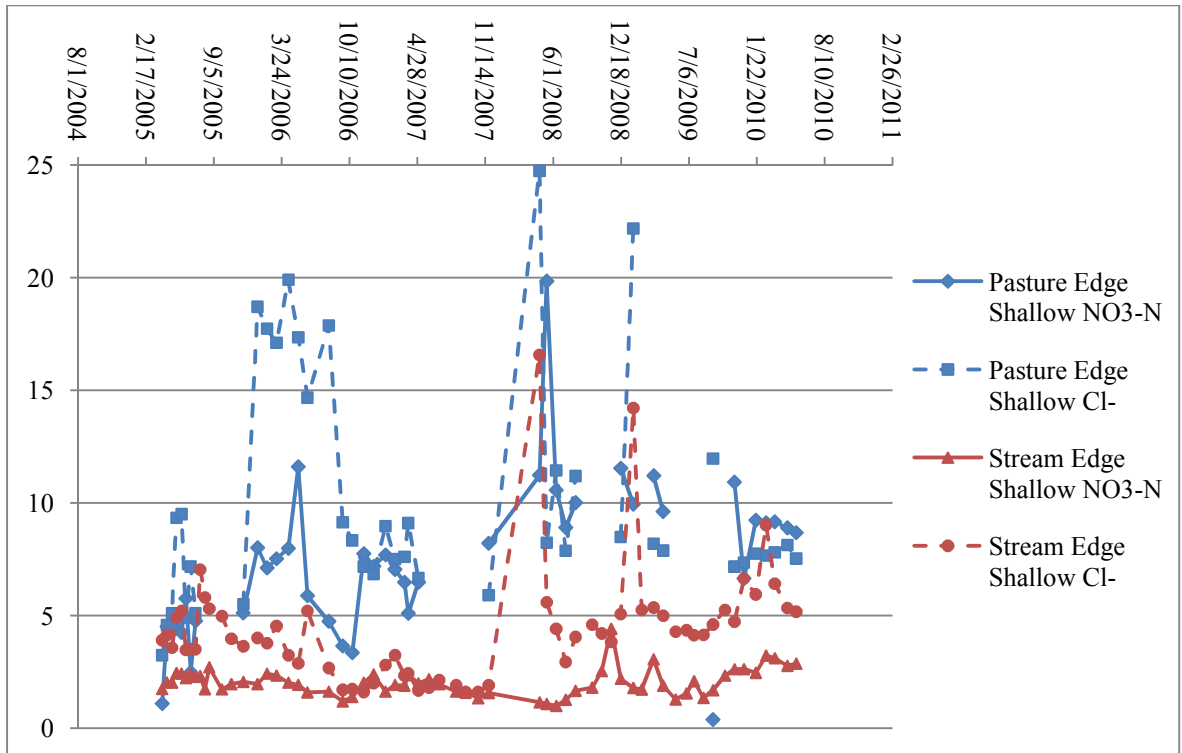


Figure 50. Block 2 mean pasture edge and stream edge NO₃-N and Cl⁻ concentrations in groundwater at the shallow depth (1.5 m) for each sampling date throughout the monitoring period.

The same analysis was performed for the 3.0 m (10 ft) depth groundwater in Block 2. Figure 51 shows the mean NO₃-N and mean Cl⁻ concentrations for each sampling date plotted throughout the entire monitoring period. The figure shows that both NO₃-N and Cl⁻ concentrations decrease between the pasture edge and stream edge for a majority of the entire monitoring period. All 62 of the paired NO₃-N samples decreased between the pasture edge and the stream edge. Many of the decreases were large, 41 of the 62 samples decreased by more than 5 mg/L but only 4 of the 62 were greater than 10 mg/L. The percent reduction in NO₃-N concentrations between the pasture edge groundwater and stream edge groundwater

ranged from 60% to 90%. The mean and median percent reductions in NO₃-N concentrations were 81% and 82% respectively.

Cl⁻ concentrations in the deeper 3.0 m (10 ft) groundwater also decreased between the pasture edge and stream edge for all of the monitoring period at the 3.0 m (10 ft) groundwater depth. All 62 of the paired Cl⁻ samples decreased between the pasture edge and the stream edge. A majority of the samples (48 out of the 62 samples) decreased by more than 5 mg/L and 7 of the 62 paired samples decreased by more than 10 mg/L. The percent reductions between the pasture edge and stream edge Cl⁻ concentrations ranged from 34% to 93%. The mean and median reductions in Cl⁻ were 70% and 69% respectively.

The same analysis that was completed for shallow 1.5 m (5 ft) depth groundwater was repeated for the deep 3.0 m (10 ft) depth to determine the amount that biological processes may have contributed to the decreases in NO₃-N concentration. Table 22 found in Appendix D shows values calculated for each sampling date. The mean and median differences between the percent reductions in NO₃-N concentrations and the percent reductions in Cl⁻ concentrations were 13% and 14% respectively. The largest difference was 53% on 4/22/2008. These values were approximately the amount of reduction in NO₃-N concentrations that could be attributed to biological removal in the buffer at the deep depth. The data was again split into a pre-2008 and post-2008 groups and analyzed due to the slight changes between the two periods. The post-2008 period again had a slightly higher biological removal of 22%. The pre-2008 showed a smaller reduction in NO₃-N that could

be attributed to biological removal. The estimated removal was 6%. It is unknown why such a large discrepancy occurred between these two periods of the study.

These removals were less than what was been reported by previous researchers who calculated removals of between 75-99% (Altman and Parizek, 1995; Schoonover and Williard, 2003; Vellidis et al., 2003). However, the values are similar to those found by Clausen et al (2000) who reported a 35% N removal in the buffer groundwater, as well as, Dukes et al. (2002) and Snyder et al. (1998) who reported ranges of 28-84% and 16-70% respectively due to variability among buffers within each of their own studies. All of these studies accounted for dilution using some form of tracer except Snyder et al. (1998).

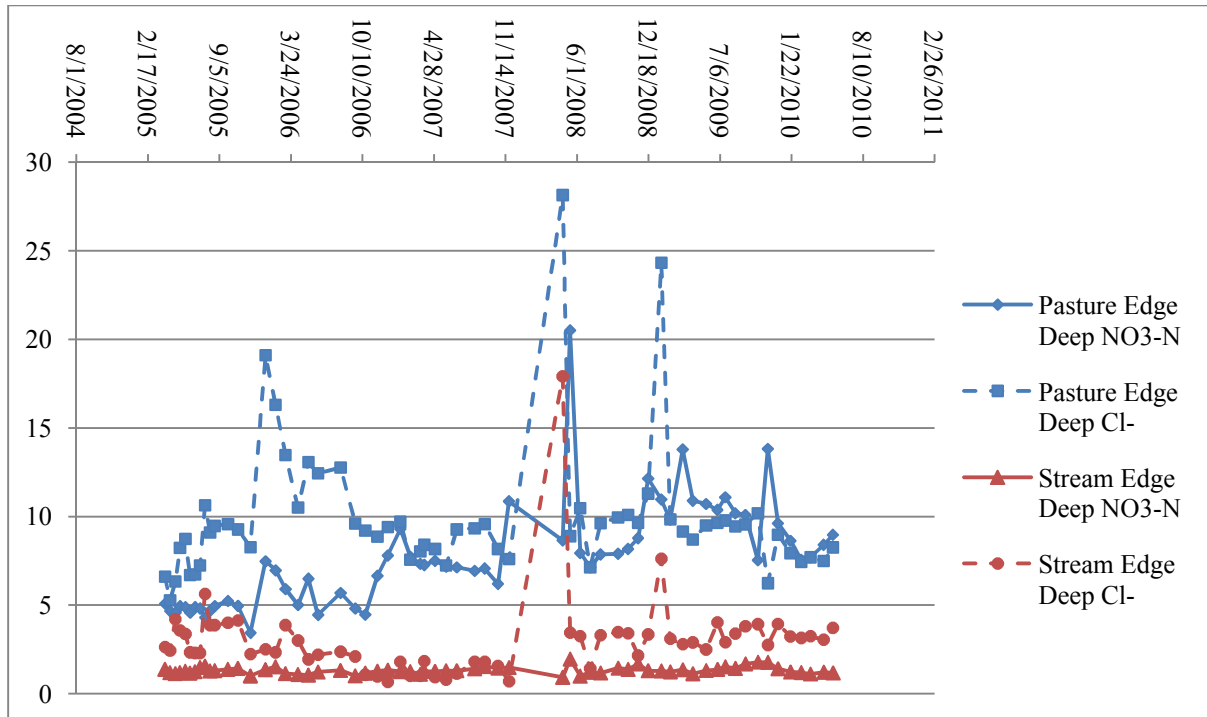


Figure 51. Block 2 mean pasture edge and stream edge NO₃-N and Cl⁻ concentrations in groundwater at the deep depth (3.0 m) for each sampling date throughout the monitoring period.

Groundwater Quality – Cations

Decreasing Cl⁻ concentrations seemed to indicate that significant groundwater mixing was occurring in the Block 2, however more evidence was sought to confirm this conclusion. Cations were assessed at the pasture edge wells and stream edge wells in the surficial aquifer and in each deep aquifer well in an attempt to establish a difference in chemistry between the deep aquifer and surficial aquifer. If unique chemistries were found between the two aquifers then it would have been possible to conclude that the two aquifers were separated and very little dilution was taking place. Likewise, if the two aquifers had the same

chemistries throughout the buffer or at a particular location in the buffer then it might indicate that dilution was occurring in that area of the buffer.

Figure 52 shows the Na^+ concentrations at different elevations in the groundwater of Block 2. Elevations above 54.6 m (179 ft) were considered a part of the surficial aquifer which included shallow (1.5 m depth) and deep (3.0 m depth) groundwater, while elevations at or below 54.6 m (179 ft) were below the saprolitic soil layer and considered a part of the deep aquifer. Similar to Block 1, no strong trend could be found based on the elevation of the groundwater wells as Na^+ concentrations were very similar between the different elevations and mean concentrations ranged between 4.0 mg/L and 8.0 mg/L. As a result, no meaningful difference between the groundwater chemistries in the deep aquifer and surficial aquifer could be established.

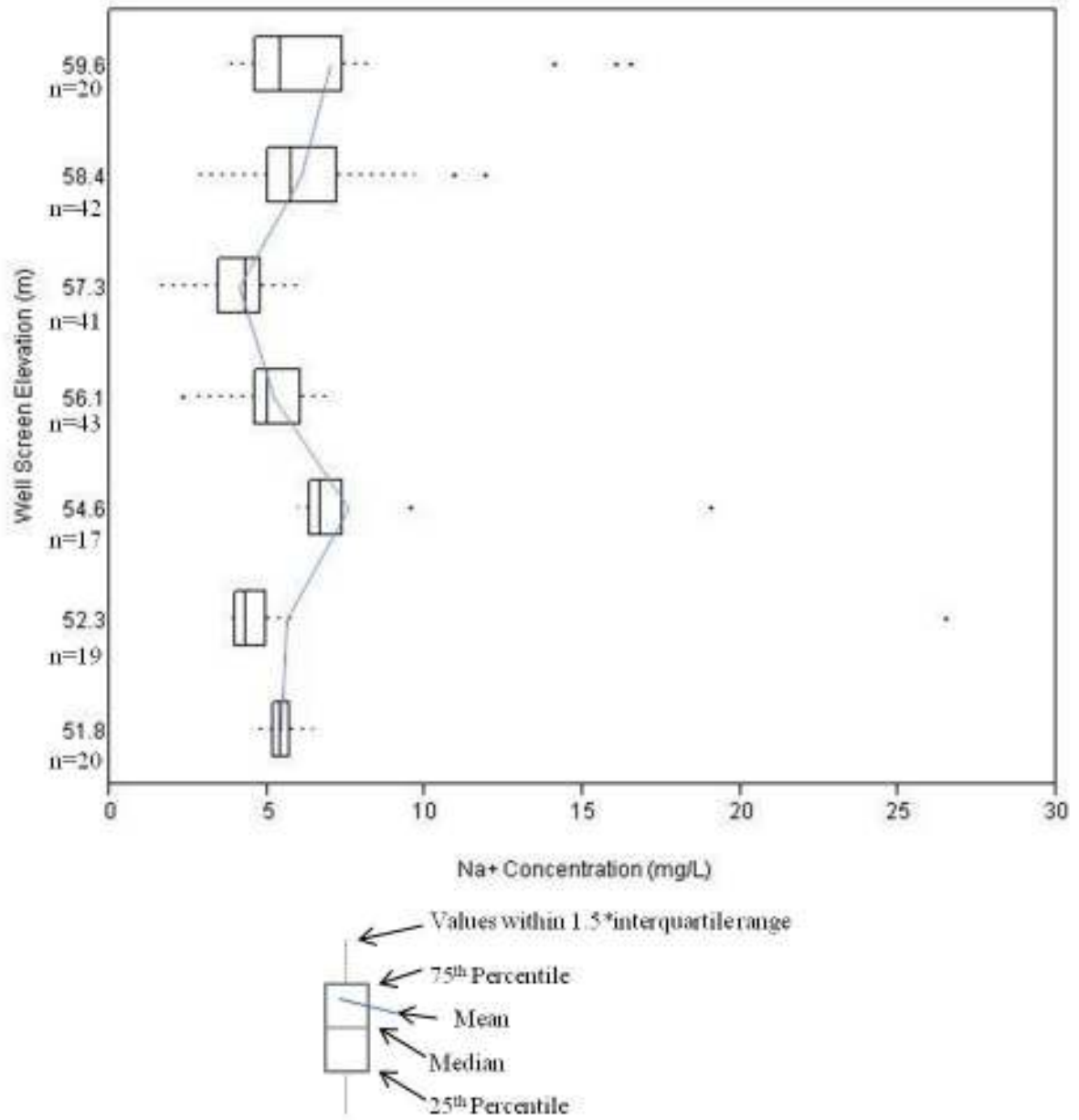


Figure 52. Block 2 Na⁺ concentrations at various well depths below the ground surface

Similarly, Figure 53 shows the Ca^{2+} concentrations in wells at different elevations of groundwater in Block 2. Ca^{2+} concentrations ranged between 4.0 mg/L and 10.0 mg/L, except for groundwater at an elevation of 54.6 m (179 ft). This groundwater was sampled in the pasture up gradient from the buffer and may indicate that a chemical difference, and thus separation of the surficial and deep aquifer, may have occurred at that location. However, as the figure shows, there was little difference between the other elevations that were actually sampled within the monitoring block of the Block 2.

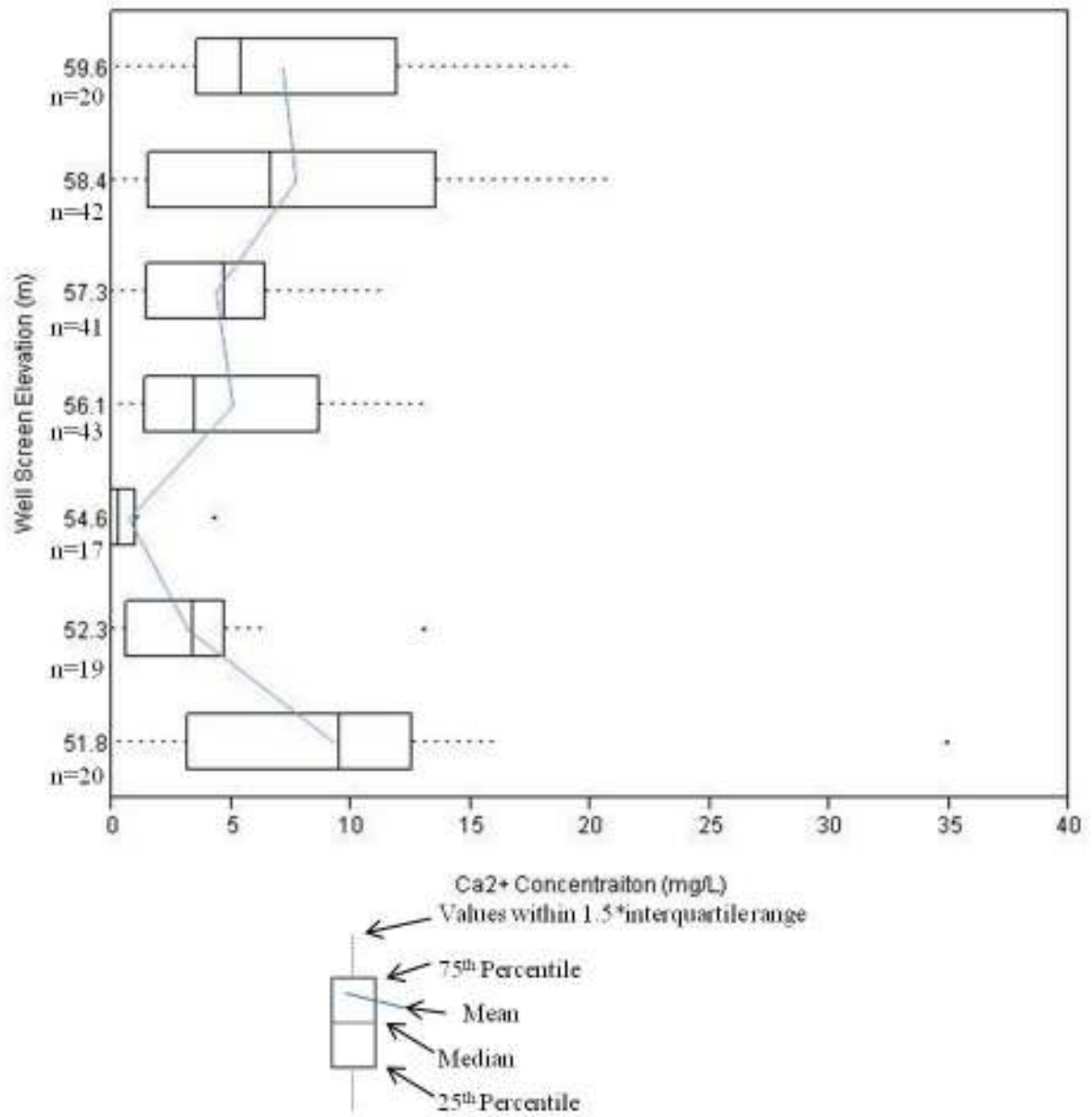


Figure 53. Block 2 Ca²⁺ concentrations at various well depths below the ground surface

Discussion and Conclusion

Significant reductions in $\text{NO}_3\text{-N}$ concentrations were observed in this monitoring block between the pasture edge groundwater and stream edge groundwater; pasture edge mean concentrations were 7.0 mg/L and 7.3 mg/L for the shallow 1.5 m (5 ft) depth groundwater and deep 3.0 m (10 ft) depth groundwater respectively. These concentrations decreased to 2.1 mg/L and 1.3 mg/L at the stream edge for the shallow 1.5 m (5 ft) depth groundwater and deep 3.0 m (10 ft) depth groundwater respectively. A mean percent reduction in $\text{NO}_3\text{-N}$ of 70% for shallow 1.5 m (5 ft) groundwater and 82% for deep 3.0 m (10ft) deep groundwater over the monitoring period were recorded. Similarly, calculated $\text{NO}_3\text{-N}$ loads were reduced substantially between the pasture edge groundwater and stream edge groundwater in the buffer. Ideally this reduction in $\text{NO}_3\text{-N}$ would have been due to denitrification in the buffer which would have resulted in complete removal of the $\text{NO}_3\text{-N}$ from the system. Several factors were studied to determine whether this loss could be attributed to denitrification or by dilution

Some measurements indicated that conditions in the buffer were conducive for denitrification to occur throughout the monitoring period. Residence time for groundwater in the monitoring block was estimated to be about 10 years, which should have been adequate for denitrification to occur. At the 3.0 m (10 ft) depth, a majority of all redox measurements recorded in Block 2 were below the +200 mV threshold where denitrification is thought to be a primary process. The shallow 1.5 m (5 ft) groundwater depth also recorded readings below both the +200 mV and +350 mV thresholds, but far less frequently than the deep probes.

This was attributed to the water table dropping below the 1.5 m (5 ft) depth during dry periods, creating aerobic conditions in the soils near the probes and making denitrification less likely. This likely limited the denitrification potential in the shallow groundwater. Mean DOC concentrations in Block 2 were probably marginal for high rates of denitrification to occur, mean well concentrations ranged from 3.9 mg/L to 9.9 mg/L throughout the monitoring period. However, spikes of DOC to concentration of nearly 10 mg/L or above, where high rates of denitrification have been measured by other researchers (Obenhuber and Lowrance, 1991), occurred sporadically throughout the monitoring period in all locations.

While these measurements supported some potential denitrification in the buffer groundwater mixing, changing flow volumes, or preferential flow paths could have played a role in the decreasing NO₃-N concentrations. For this reasons, NO₃-N concentrations normalized by Cl⁻ concentrations were thought to be a better indicator of the fate of NO₃-N. NO₃-N/Cl⁻ ratios were also found to decrease between the pasture edge groundwater and stream edge groundwater for both the 1.5 m (5 ft) and 3.0 m (10 ft) groundwater depths. This would imply that biological removal of the NO₃-N was occurring. Cl⁻ concentrations were found to significantly decrease between the pasture edge groundwater and stream edge groundwater for both the 1.5 m (5 ft) and 3.0 m (10 ft) depths, which indicated that not all of the reduction in NO₃-N concentrations was due to biological processes (denitrification or vegetation uptake) but a significant amount was also caused by dilution by a NO₃-N and Cl⁻ poor aquifer or rainfall. Analysis of Cl⁻ samples on each sampling date indicated that these reductions occurred for a majority of the sampling period and that reductions in NO₃-N

concentrations across the buffer were on average only slightly more than decreases in Cl^- concentrations between the pasture edge groundwater and stream edge groundwater. At the 1.5 m (5ft) groundwater depth $\text{NO}_3\text{-N}$ concentrations were reduced on average by 20% more than Cl^- concentrations. At the 3.0 m (10 ft) groundwater depth, mean $\text{NO}_3\text{-N}$ concentrations were reduced by 13%. These reductions were thought to be the maximum amount of reduction in $\text{NO}_3\text{-N}$ concentrations that could be attributed to biological transformation, most likely by denitrification.

It should be noted that Cl^- concentrations fluctuated throughout a large range at the pasture edge during the monitoring period. Often concentrations tracked very nearly with $\text{NO}_3\text{-N}$ concentrations although not in all cases and the variability made interpretation of the data with high confidence difficult. Variability of Cl^- concentrations at the pasture edge were thought to be due to both the variability in the poultry litter source as well as possible uneven application of the litter to the pasture. This seemed to be a major drawback to the $\text{NO}_3\text{-N} / \text{Cl}^-$ technique at this site. Despite these difficulties, data indicated that both dilution and denitrification of NO_3^- likely occurred in Block 2. Future work researching this monitoring block or other riparian buffers should take these findings into account and possibly use other techniques to account for dilution and denitrification.

While dilution due to groundwater mixing is not the preferred process of $\text{NO}_3\text{-N}$ concentration reduction in riparian buffers, Block 2 may have still had an important role in improving water quality. The $\text{NO}_3\text{-N}$ load entering the stream would have likely been

greater if the pasture had extended all the way to the edge of the stream due to increased surface runoff and an increase in the NO₃-N laden contributing area. The buffer acted as a barrier to surface runoff and a physical area where almost no additional NO₃-N would be added to the groundwater so that NO₃-N concentrations, from the pasture, could be diluted or transformed.

It is also important to note that further NO₃-N losses may have occurred as groundwater was being discharged through the hyporheic zone of the stream. Significant denitrification has been observed in other studies in this area of riparian buffers (Spruill, 2000). This would have increased the overall effectiveness of the buffer had the transformations been considered.

Other future work in this monitoring block could investigate the effect of the stream incision on the buffer effectiveness. As mentioned in the site description, the stream was incised between 1.2-1.5 m (4-5 ft) throughout Block 1, lowering the water table in the block especially along the stream edge. High water tables are considered an important characteristic of riparian buffers when NO₃⁻ reduction in groundwater is a major goal. In Block 2, higher water tables could provide anaerobic conditions for longer periods of each year and could possibly increase DOC concentrations in groundwater by leaching carbon from the upper horizons of the soil which could possibly translate to higher overall denitrification rates.

References

- Addy, K.L.; Gold, A.J.; Groffman, P.M.; Jacinthe, P.A. 1999. Ground water nitrate removal in subsoil of forested and mowed riparian buffer zones. *Journal of Environmental Quality* 28, 962-970.
- Ambus, Per and Lowrance, Richard. 1991. Comparison of denitrification in two riparian soils. *Soil Science Society of America Journal* 55(4), 994-997.
- Altman, S.J. and R.R. Parizek. 1995. Dilution of nonpoint-source nitrate in groundwater. *Journal of Environmental Quality* 24, 707-718.
- Aravena, R. and W.D. Robertson. 1998. Use of multiple isotope tracers to evaluate denitrification in ground water: Study of nitrate from a large-flux septic system plume. *Groundwater* 36 (6), 975-982.
- Bailey, L.D., and E.G. Beauchamp. 1973. Effects of moisture, added NO_3^- , and macerated roots on NO_3^- transformation and redox potential in surface and subsurface soils. *Canadian Journal of Soil Science* 53(2), 219-230.
- Beaulac, M.N., and K.H. Reckhow. 1982. An examination of land use – nutrient export relationships. *Water Resources Bulletin* 18 (6), 1013-1024.
- Böhlke, J.K. and Denver, J.M. 1995. Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland. *Water Resources Research* 31(9), 2319-2339.
- Christensen, T.H., Bjerg, P.L., Banwart, S.A., Jakobsen, R., Heron, G. Albrechtsen, H. 2000. Characterization of redox conditions in groundwater contaminant plumes. *Journal of Contaminant Hydrology* 25, 165-241.
- Clausen, J.C., Guillard, K., Sigmund, C.M., Dors, K. Martin. 2000. Water quality changes from riparian buffer restoration in Connecticut. *Journal of Environmental Quality* 29(6), 1751-1761.
- Dukes, M.D.; Evans, R.O.; Gilliam, J.W.; Kunickis, S.H. 2002. Effect of riparian buffer width and vegetation type on shallow groundwater quality in the middle coastal plain

- of North Carolina. *Transactions of the American Society of Agricultural Engineers* 45(2), 327-336.
- Fieldler, S., M.J. Vepraskas, and J.L. Richardson. 2007. Soil redox potential: Importance, field measurements, and observations. *Advances in Agronomy* 94, 1-54.
- Gillham, R.W., R.C. Star, D.J. Miller. 1990. A Device for in-situ determination of geochemical transport parameters. *Groundwater* 28 (6). 858-862.
- Hill, A.R. 1996. Nitrate removal in stream riparian zones. *Journal of Environmental Quality* 25, 743-755.
- Hubbard, R.K.; Newton, G.L.; Davis, J.G.; Lowrance, R.; Vellidis, G.; Dove, C.R. 1998. Nitrogen assimilation by riparian buffer systems receiving swine lagoon wastewater. *Transactions of the American Society of Agricultural Engineers* 41(5), 1295-1304.
- Kilmer, V.J., J.W. Gilliam, J.F. Lutz, R.T. Joyce, and C.D. Eklund. 1974. Nutrient losses from fertilized grassed watersheds in Western North Carolina. *Journal of Environmental Quality* 3 (3), 214-219.
- Knowles, R., 1982. Denitrification. *Microbiological Reviews* 46 (1), 43-70.
- Kralova, M., P.H. Masscheleyn, C.W. Lindau, W.H. Patrick, Jr. 1992. Production of dinitrogen and nitrous oxide in soil suspensions as affected by redox potential. *Water, Air, and Soil Pollution* 61, 37-45.
- Larsen, D., R.W. Gentry, and D.K. Solomon. 2002. The geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA. *Applied Geochemistry* 18, 1043-1063.

- Line, D.E., W.A. Harman, G.D. Jennings, E.J. Thompson, and D.L. Osmond. 2000. Nonpoint-source pollutant load reductions associated with livestock exclusion. *Journal of Environmental Quality* 29, 1882-1890.
- Line, D.E., N.M. White, D.L. Osmond, G.D. Jennings, and C.B. Mojonner. 2002. Pollutant export from various land uses in the upper Neuse River Basin. *Water Environment Research* 74 (1), 100-108.
- Martin, T.I.; Kaushik, N.K.; Trevors, J.T.; Whiteley, H.R. 1999. Review: Denitrification in temperate climate riparian zones. *Water, Air, and Soil Pollution* 111, 171-186.
- Mengis, M.; Schiff, S.L.; Harris, M.; English, M.C.; Aravena, R.; Elgood, R.J.; MacLean. 1999. Multiple geochemical and isotopic approaches for assessing ground water NO_3^- elimination in a riparian zone. *Ground Water* 37(3), 448-457.
- Natural Resource Conservation Service. 2008. Web soil survey: Halifax County, NC. Available at <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>. Accessed on April 15, 2009.
- Nicholson, F.A., B.J. Chambers, and K.A. Smith. 1996. Nutrient composition of poultry manures in England and Wales. *Bioresource Technology* 58, 279-284.
- Obenhuber, D.C. and R. Lowrance. 1991. Reduction of nitrate in aquifer microcosms by carbon additions. *Journal of Environmental Quality* 20(1), 255-258.
- Puckett, L.J. 2004. Hydrogeologic controls on the transport and fate of nitrate in ground water beneath riparian buffer zones: Results from thirteen studies across the United States. *Water Science and Technology* 49(3), 47-53.
- Rawls, W.J., D. Gimenez, and R. Grossman. 1998. Use of soil texture, bulk density, and slope of water retention curve to predict saturated hydraulic conductivity. *Transactions of the ASAE* 41 (4), 983-988.
- Saxton, K.E. and W.J. Rawls. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *United States Department of Agriculture and Washington State University*. Accessed at <http://hydrolab.arsusda.gov/SPAW/Index.htm>.

- Schoonover, Jon E.; Williard, Karl W.J. 2003. Ground water nitrate reduction in giant cane and forest riparian buffer zones. *Journal of the American Water Resources Association* 39(2), 347-354.
- Schwartz, F.W. and H. Zhang. 2003. *Fundamentals of Groundwater*. New York, N.Y.: John Wiley and Sons.
- Sóvik, A.K. and P.T. Mørkved. 2007. Nitrogen isotope fractionation as a tool for determining denitrification in constructed wetlands. *Water Science and Technology* 56 (3), 167-173.
- Snyder, N.J., S. Mostaghimi, D.F. Berry, R.B. Reneau, S. Hong, P.W. McClellan, and E.P. Smith. 1998. Impact of riparian forest buffers on agricultural nonpoint source pollution. *Journal of the American Water Resources Association* 34(2), 385-395.
- Spruill, Timothy B. 2000. Statistical evaluation of effects of riparian buffers on nitrate and ground water quality. *Journal of Environmental Quality* 29, 1523-1538.
- State Climate Office of North Carolina. Enfield Weather Station (ID# 312827). *North Carolina Climate Retrieval and Observations Network of the Southeast Database (NC CRONOS)*. Accessed at <http://www.nc-climate.ncsu.edu/services/request.php>.
- Starr, R.C. and R.W. Gillham. 1993. Denitrification and organic carbon availability in two aquifers. *Groundwater* 31(6), 934-947.
- Stefansson, A., S. Arnorsson, A.E. Sveinbjornsdottir. 2005. Redox reactions and potential in natural waters at disequilibrium. *Chemical Geology* 221, 289-311.
- United States Army Corps of Engineers. 1987. Corps of Engineers Wetland Delineation Manual. Accessed at <http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf>.
- Van Beers, W.F.J. 1958. The auger hole method: A field measurement of the hydraulic conductivity of soil below the water table. *International Institute for Land Reclamation and Improvement*. 1-23.

- Vellidis, G.; Lowrance, R.; Gay, P.; Hubbard, R.K. 2003. Nutrient transport in a restored riparian wetland. *Journal of Environmental Quality* 32, 711-726.
- Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA-FS publication No. NA-PR-07-91. Radnor, Pa.: USDA-FS. Accessed at http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm.
- Wafer, C.C., R.J. Barrett, and D.L. Osmond. 2004. Construction of platinum-tipped redox probes for determining soil redox potential. *Journal of Environmental Quality* 33 (6), 2375-2379.
- Zublena, J.P., J.C. Barker, T.A. Carter. 1996. Poultry manure as a Fertilizer source. *North Carolina Cooperative Extension Service*. Pub. No. AG-439-5. Accessed at: http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag439_5.html

CHAPTER 4: FATE OF NITRATE AND HYDROLOGY OF MONITORING BLOCK 3

Introduction

The goal of this study was to apply several measurement techniques to a CREP enrolled buffer and determine the fate of groundwater NO_3^- as it moved through the buffer. Understanding the role of denitrification and dilution in the fate of NO_3^- at the field scale will lead to better buffer design and placement in the landscape. If individual processes can be linked to easily measurable characteristics of the buffer, generalized rapid assessment techniques should become more accurate and feasible. Then planners will be able to better allocate resources to those buffers that are predicted to have the greatest affect on improving water quality. Due to the variability between buffers at different sites, and even differences in buffers at the same site, many studies will need to be performed before accurate general guidelines can be established. With this in mind, the analysis that was performed in Chapter 2 and Chapter 3 was repeated in a different area of the buffer to determine how the effectiveness of the buffer might vary. A new monitoring block, Block 3, was established at a higher elevation than Block 1 and Block 2, but with the same dimensions and instrumentation.

Materials and Methods

Site Description

Block 3 was the most upstream monitoring block at the research site. Up gradient from the buffer the pasture application rate of $\text{NO}_3\text{-N}$ was the same as the rest of the site, about 41 kg-N/ha. The contributing area was estimated to be 3.5 ha about the same as Block 2 and about 1 ha larger than Block 1. Upland slopes in this area of the buffer were about 0.036, slightly less than Block 1 or Block 2. The buffer design was the same as the other blocks, with 3 zones and similar vegetation and the stream was incised by between 1.2 m and 1.8 m (4 ft to 6 ft).

Soils Description

NRCS soils survey (NRCS, 2008) showed the soils were similar to Block 1 and Block 2, Goldsboro fine sandy loam within the buffer and a mix of Bonneau loamy fine sand and Emporia-Wedowee sandy loam complex in the pasture.

Soil cores taken at the site showed that soils in the pasture upslope from Block 3 consisted of clayey silts near the surface with some fine sand that extended to a depth of about 2.4 m (8.0 ft) below the ground surface. A clayey silt saprolite layer occurred below this depth and continued to auger refusal. Soils inside the buffer at the pasture edge were a brown and tan fine to medium sand with increasing silt with depth from the surface. At about 1.5 m (5 ft) below the soil surface the color changed to light-gray fine sand with some rounded gravels down to about 3.0 m (10 ft) from the surface. At about 3.0 m (10 ft) to 3.7 m

(12ft) a tightly packed gray clayey silt layer occurred and then fine to medium sands until 4.6 m (15 ft) when sampling was stopped due to soil collapsing around the sampling hole. A saprolitic layer that was similar to the other blocks at the site was not encountered in Block 3. At the stream edge the soils from the surface down to about 3.7 m (12 ft) below the ground surface were brownish gray clayey fine to medium sand and became more clay rich with depth. From 3.7 m to 5.5 m (12 ft to 18 ft) the soils were gray fine to coarse sand with trace gravels and were described as loose, runny, and homogeneous. From 5.5 m (18 ft) to auger refusal at 7.3 m (24 ft) the soil was a yellow or orange silty medium sand. Figure 54 shows the soil textures at different topographic positions in the buffer.

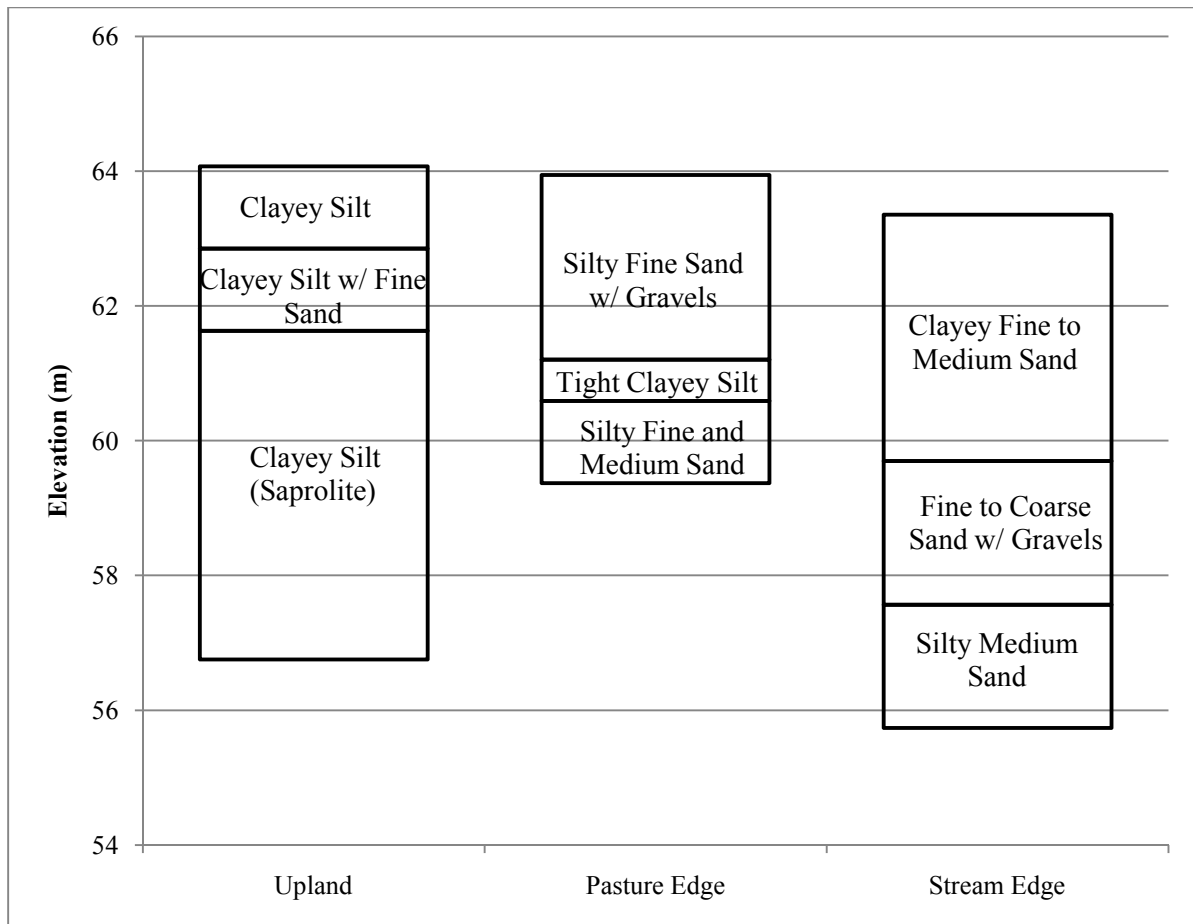


Figure 54. . Block 2 soils at different topographic positions

Monitoring

Figure 55 shows the monitoring layout for Block 3. The instrument and monitoring well layout was similar to Block 2. Surficial aquifer wells were installed at the same time and in the same manner as wells in Block 1 and Block 2 (See Groundwater Monitoring in Chapter 2). Redox potential probes were located at each well position in Transect B along with water table depth loggers at the pasture edge and stream edge (See Redox Potential

Probes and Water Table Measurements in Chapter 2). Shallow wells were installed at a depth of 1.5 m (5 ft) below the ground surface and deep wells were installed at 3.0 m (10 ft) below the ground surface. Plots in this chapter may have select water quality data removed to improve clarity. The location of the removed data will be noted in the caption under each graph using the following method: PE denotes pasture edge (well position 1), MB denotes the mid-buffer (well position 2), and SE denotes the stream edge (well position 3). The depth of each well was also included with S denoting the shallow depth (1.5 m depth) and D denoting the deep depth (3.0 m).

Redox potential probes were located at each well position in transect B and were installed at the same depths below the ground surface as the shallow and deep wells. Water table depth loggers were positioned at the pasture edge and stream edge locations.

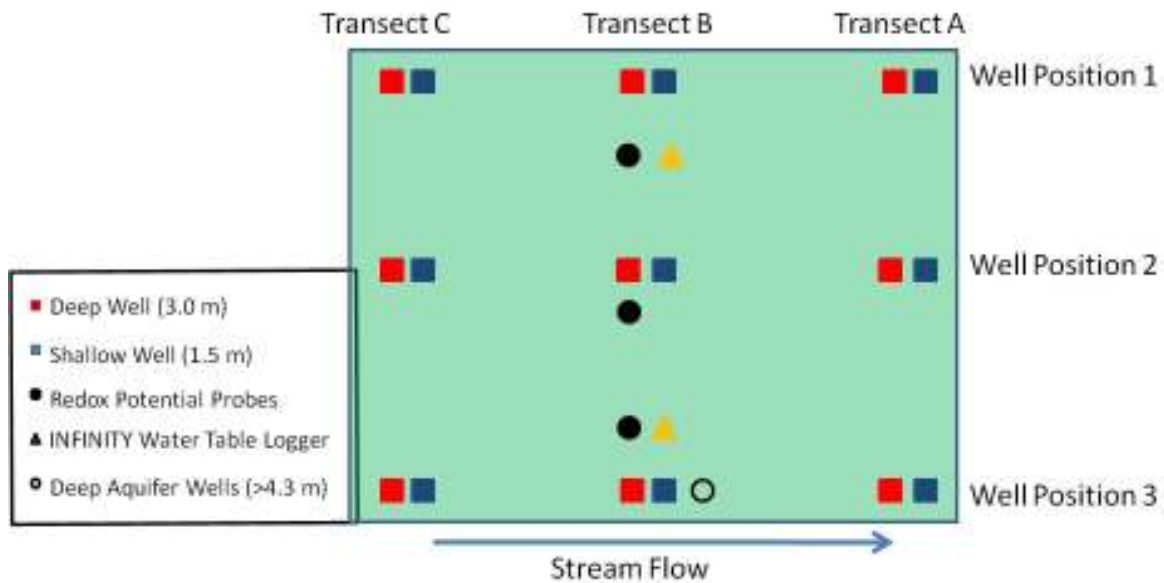


Figure 55. Block 3 monitoring well and instrumentation layout.

Only a single deep aquifer well was installed in Block 3. It was installed at the same time as those in Block 1 and Block 2 using the same protocol (See Groundwater Monitoring in Chapter 2). The well was placed at the stream edge in transect B and was installed at a depth of 4.3 m (14 ft) below the ground surface. No well was placed at the pasture edge in this block because of difficulties during installation. Soils at the depth the well was to be installed at were very sandy and tended to collapse around the auger hole. Figure 56 shows a profile view of the Block 3 and the location and depth of the monitoring wells.

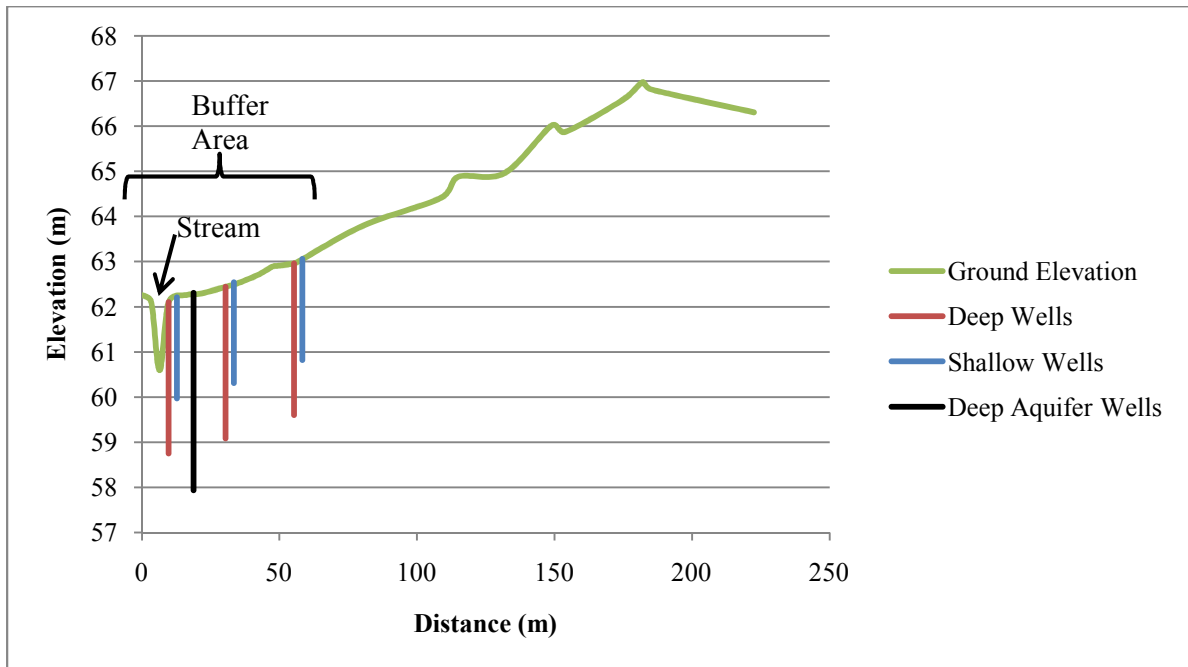


Figure 56. Block 3 ground profile and monitoring well locations and relative depths.

All groundwater wells and water level data loggers were constructed and installed in the same manner as those in Block 1. Groundwater quality sampling in Block 3 used the

same protocols and sampling frequencies that were reported for Block 1 (See Groundwater Quality Sampling in Chapter 2). Soil samples were also obtained in the same manner as those procedure reported in Chapter 2 (See Soil Sampling), except that DEA samples were only taken in the transect B of Block 3, instead of samples being taken in transects A and transect C. Redox probe installation and measurements were also the same in Block 2 as those found in Block 1 (See Redox Potential Probes Section in Chapter 2). Redox probes were installed at the same depths as the shallow and deep water quality wells

Load and Residence Time Calculations

NO₃-N loads and residence time were calculated for the monitoring period for both the shallow and deep surficial monitoring well using the same formulas and methods found in Chapter 2 with some small exceptions (See Flux and Load Calculations and Residence Time). Saturated hydraulic conductivities were obtained from Table 12 below and the datum's used in calculating Darcy's law were changed to reflect Block 3. The deep layer datum was set at an elevation of 57.6 m (189 ft) and the shallow layer datum was set to 59.7 m (196 ft).

Results

Particle Size and Hydraulic Conductivity

To obtain saturated hydraulic conductivities for the site, first the auger hole method (Van Beers, 1970) was used. No measurements could be obtained in Block 3 due to the water table depth below the ground surface and equipment limitations. This method was

abandoned for the Soil-Pond-Atmosphere-Water (SPAW) Field and Pond Hydrology model (Saxton, version 6.02.75) derived from research by Saxton and Rawls (2006). Using the soil-water characteristics function and the information gained from the particle size analysis of the buffer accurate hydraulic conductivities of individual samples were made.

Table 12 shows the sand content and saturated hydraulic conductivities that were found in Block 3. The 180 cm and 330 cm depths correspond to depth below the ground surface of the mid point of the well screens of the shallow and deep well screens.

Table 11. Block 3 Sand content and hydraulic conductivity at different depths below the ground surface

Depth Below Ground Surface	Pasture Edge		Mid-Buffer		Stream Edge	
	Sand (%)	Hydraulic Conductivity (cm/hr)	Sand (%)	Hydraulic Conductivity (cm/hr)	Sand (%)	Hydraulic Conductivity (cm/hr)
30 cm	70	7.6	48	3.0	48	3.3
50 cm	79	8.0	55	0.8	60	4.7
80 cm	85	8.0	58	1.0	71	5.1
180 cm	83	6.4	80	3.9	83	4.1
330 cm	87	6.9	82	4.0	90	9.3

Hydrology

The pasture edge and stream edge water table loggers recorded depths for 92% and 86% of the total hours during the monitoring period respectively, capturing a majority of the fluctuations in the water table. Figure 57 shows the water table at the pasture edge and stream edge for Block 3 in 2009. As expected, the water table was closest to the ground

surface during the winter and early spring. It usually reached its lowest elevations during the autumn months. Late spring and summer months had an overall decreasing trend in water table elevations except when large rain events briefly raised the water table to elevations similar to those found in winter. Figure 57 is typical for all monitored years in Block 3 except 2006, which had higher water tables during the summer due to the tropical weather systems mentioned previously.

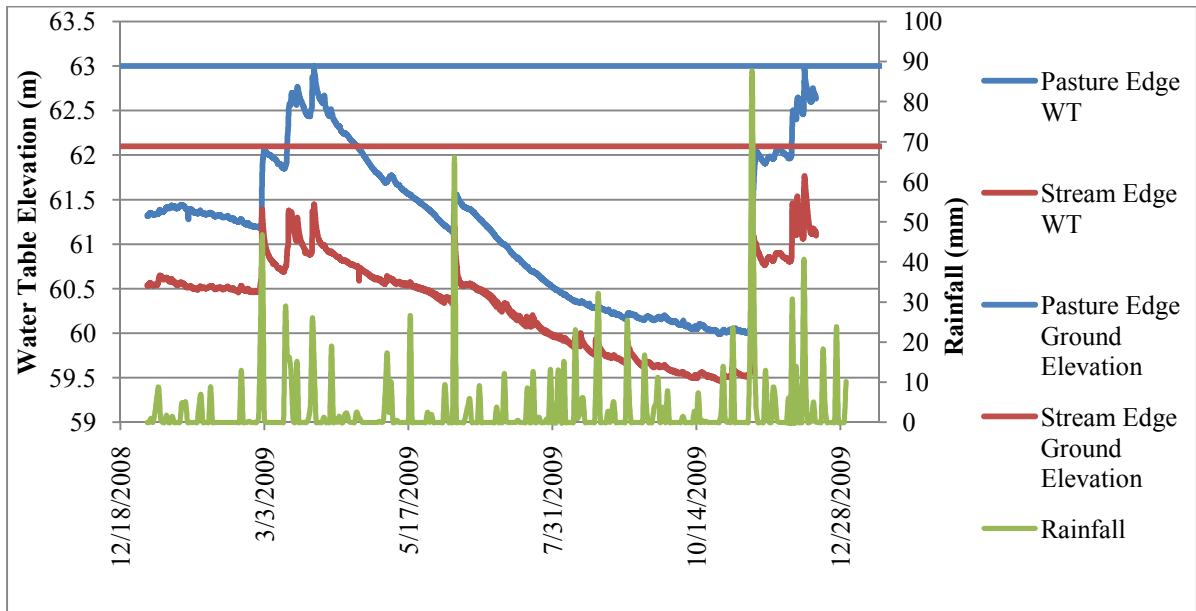


Figure 57. Block 3 water table elevations at the pasture edge and stream edge and rainfall for 2009.

Water Table Proximity to the Ground Surface

High water tables are often associated with denitrification, because they typically have anaerobic soil conditions necessary for denitrification to occur. Wetlands, for example, are identified as prime ecosystems for denitrification and have high NO₃-N removal.

Analyzing the water table depth below the ground surface put the relative wetness of different areas of the buffer into perspective. Table 12 shows the percent of each year that the water table was recorded above the specified depth. At the pasture edge the water table was rarely within 60 cm of the ground surface. At the stream edge, it was even rarer for the water table to rise within 60 cm. A water table within 60 cm of the ground surface indicates that the water table was within the root zone. The root zone is significant because roots are thought to be a source of carbon to drive denitrification or vegetation could potentially uptake NO_3^- in the groundwater. Neither location met the hydrology requirements for wetland classification of the water table rising within 30 cm of the ground surface for 5% of the growing season (USACE, 1987). The year with the highest water table was 2006 and 2009 were the two years with the highest water tables and were also years with the highest rainfalls in the monitoring period. The other years were fairly similar in proximity to the ground surface.

Table 12. Percent of total year water table was at or above specified depth below the ground surface for Block 3.

Year	Pasture Edge			Stream Edge		
	0cm	30cm	60cm	0cm	30cm	60cm
2005	0%	0%	0%	0%	0%	0%
2006	0%	1%	9%	0%	0%	1%
2007	0%	0%	1%	0%	0%	0%
2008	0%	2%	8%	0%	0%	0%
2009	0%	7%	15%	0%	0%	1%
Mean	0%	2%	7%	0%	0%	1%

Groundwater Flow Direction

Figure 58 shows the groundwater flow directions in Block 3 in September 2008, a dry period, and March 2009, a relatively wet period. The groundwater contours in September (Figure 56b) showed that water moved nearly parallel to the stream flow, especially along the stream edge well positions in the buffer. This month represents the most extreme case of parallel flow measured in this block between September 2008 and May 2010. In March (Figure 56a), when water tables were higher, the groundwater flow moves nearly perpendicular to stream flow from the pasture edge to the stream edge. Only 5 of the 18 months that manual groundwater measurements were taken showed significant groundwater flow that was parallel to the stream. These months usually included July through October. Groundwater flux calculations and groundwater quality analysis all used the assumption of perpendicular flow through the buffer because the length of each year that groundwater flowed parallel to the direction of stream flow was short.

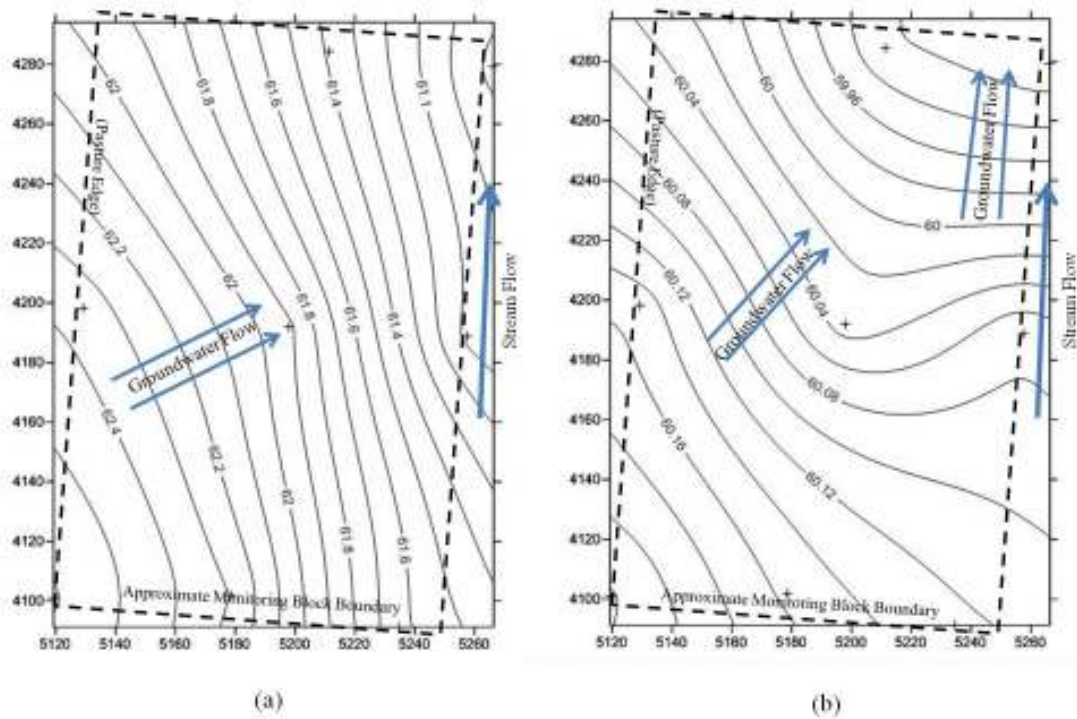


Figure 58. Block 3 groundwater flow directions in (a) March 2009 (wet period) and (b) September 2008 (dry period). Topographic lines represent elevations of the water table in meters. + signs indicate monitoring well locations where groundwater elevation was measured.

Residence Time

Residence time calculations for Block 3 indicated the minimum time for groundwater to move through the buffer was about 0.8 years. The maximum residence time could not be calculated because of negative gradients. A negative gradient indicates that water was flowing from the stream toward the pasture edge, meaning essentially that the water would never be discharged to the stream if the gradient remained at this value. Less than 1% of all calculated gradients were negative in Block 3. The median residence time was 2.3 years

while the mean was about 2.2 years. It is important to note that groundwater movement was not at a constant velocity through the buffer. Instead groundwater likely moved more rapidly during some parts of the year, then slowed down, possibly at times even flowing from the stream into the stream edge of the buffer, and as found in the groundwater direction flowed from the upstream part of the buffer to the downstream for brief periods. These details indicate that the mean and median residence times presented here were likely shorter than the actual residence times of the buffer.

Groundwater Quality – Nitrate (NO₃⁻)

Nitrate-nitrogen concentrations were sampled and assessed in the groundwater to determine if concentrations and loads decreased as the groundwater moved from the pasture edge to the stream edge. Figure 59 is a boxplot of deep 3.0 m (10 ft) depth and shallow 1.5 m (5 ft) depth groundwater NO₃-N concentrations in Block 3. The figure shows a large decrease in median concentration from the pasture edge (well position 1) to the mid-buffer (well position 2) and a slight decrease in concentration from the mid-buffer to stream edge (well position 3) wells for both deep and shallow wells. This would seem to indicate that NO₃-N was being removed, by vegetation, diluted by groundwater mixing, or being removed via denitrification as the groundwater moved from the pasture edge to the stream edge.

Groundwater at the pasture edge had the largest range of concentrations compared to the other well positions. Shallow pasture edge groundwater ranged from 0.2 mg/L to 12.3 mg/L while the deep pasture edge concentrations ranged from 0.4 mg/L to 17.2 mg/L.

Shallow groundwater at the mid-buffer ranged from 0.0 mg/L to 6.0 mg/L and mid-buffer deep groundwater ranged from 0.1 mg/L to 8.0 mg/L. Finally, groundwater at the stream edge had the smallest range of sampled values ranging from 0.1 mg/L to 6.0 mg/L for the shallow 1.5 m (5 ft) depth and from 0.1 mg/L to 6.1 mg/L for the deep 3.0 m (10 ft) depth.

Mean concentration values were similar to the medians shown in Figure 59. The pasture edge mean concentration was 4.5 mg/L for shallow groundwater and 5.8 mg/L for deep groundwater. At the mid-buffer mean concentrations were 1.0 mg/L and 3.0 mg/L, while stream edge groundwater mean concentrations were 0.8 mg/L and 1.7 mg/L for the shallow 1.5 m (5 ft) and deep 3.0 m (10 ft) depths respectively. These values corresponded to a percent reduction in mean concentrations of 82% for the shallow depth and 71% for the deep depth between the pasture edge and stream edge.

Statistical analysis showed that shallow and deep pasture edge groundwater was significantly different from the corresponding mid-buffer and stream edge groundwater, but the difference in concentrations between mid-buffer groundwater and stream edge groundwater of the same depth was not found to be statistically significant ($p = 0.9557$ and $p = 0.3118$ for shallow and deep respectively).

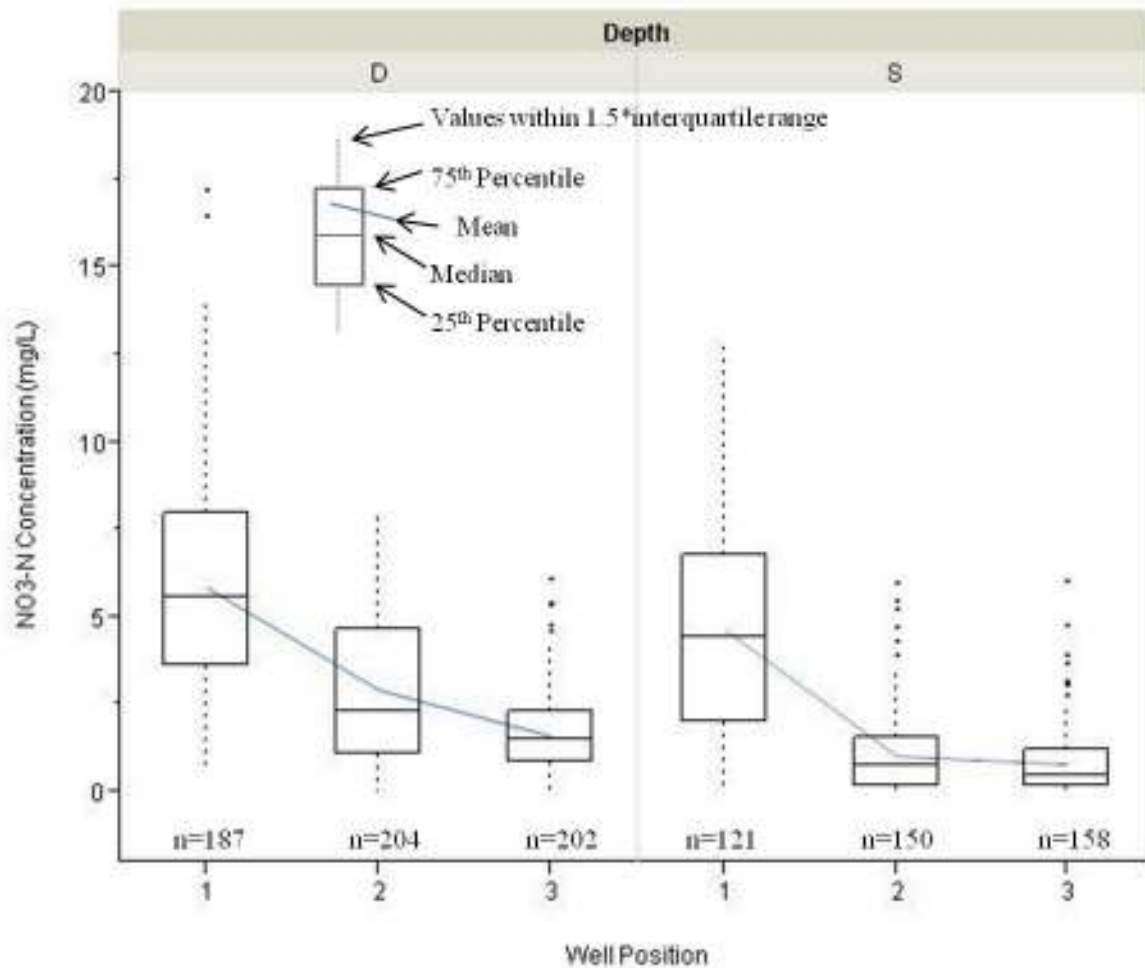


Figure 59. Block 3 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater NO₃-N concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at each well position.

Differences in groundwater concentrations between transects in Block 2 are shown in Figure 60 for shallow groundwater and Figure 61 for deep groundwater. All transects showed a decrease in concentrations between the pasture edge well position and the stream edge well position. Shallow groundwater transects displayed similar mean and median NO₃-

N concentrations between all mid-buffer and stream edge well positions. Mean and median well concentration values only ranged by about 0.7 mg/L between the different well positions. At the pasture edge, transect A had a lower median and mean concentration compared to transects B and C by about 2-3 mg/L (mean concentrations of 3.0 mg for transect A and 5.3 mg/L and 4.9 mg/L for transects B and C respectively).

Deep groundwater in Block 3 had many differences between transects. Transect B had a much higher pasture edge mean and median concentration when compared with transects A and C (mean concentrations of 8.2 mg/L, 3.9 mg/L and 5.0 mg/L respectively). At the mid-buffer well position transect C showed an elevated mean concentration of 5.0 mg/L, the same as the transect C pasture edge concentration. It was also much higher when compared to the transect A and B concentrations (2.8 mg/L and 1.0 mg/L respectively). Possible explanation for the fluctuations among well positions was preferential flow paths in the buffer or localized surface run-off that transported more water and NO₃-N to certain wells in the buffer. Another possibility was groundwater mixing causing dilution of concentrations in other wells. At the stream edge all of the groundwater concentrations were very similar with mean well concentrations ranging from 1.1 mg/L to 2.1 mg/L.

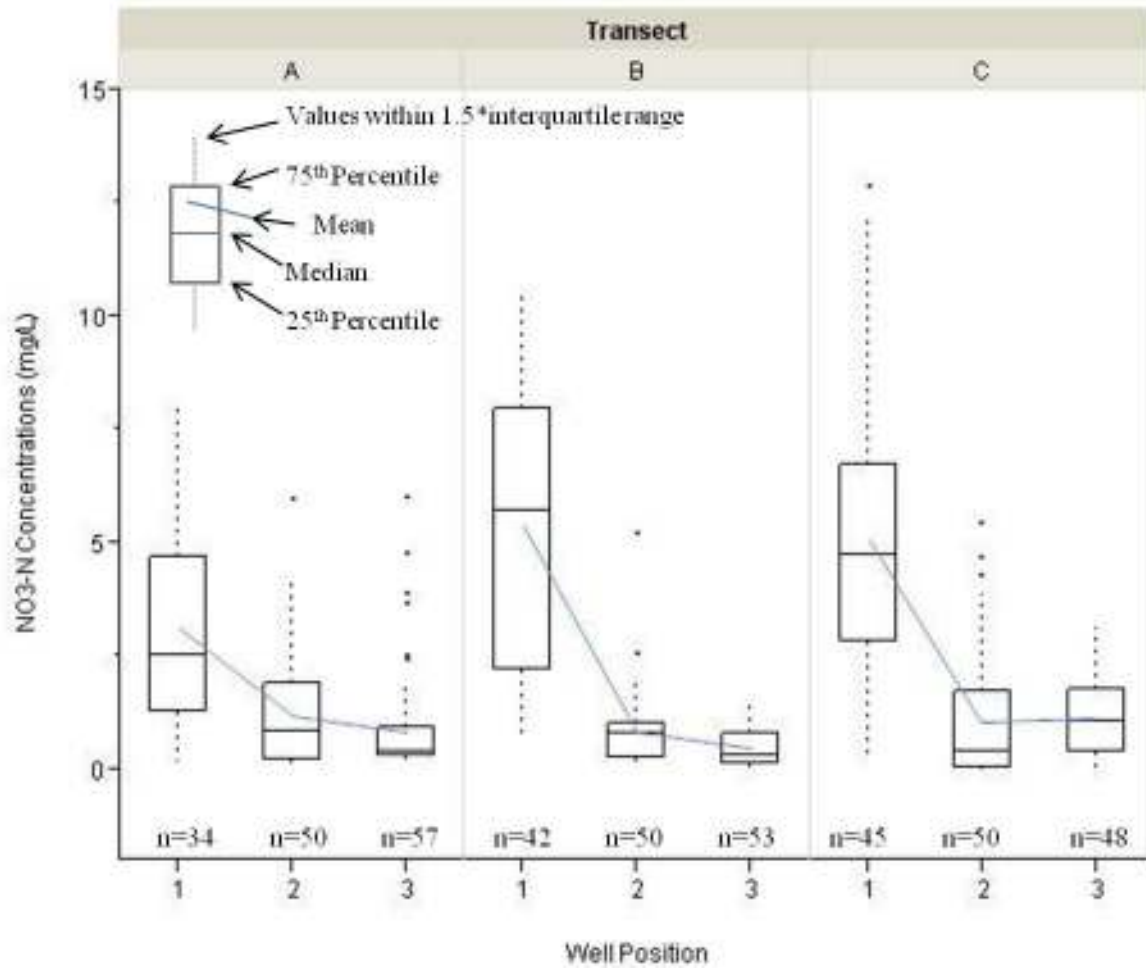


Figure 60. Block 3 shallow (1.5 m depth) groundwater NO₃-N concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at each well position.

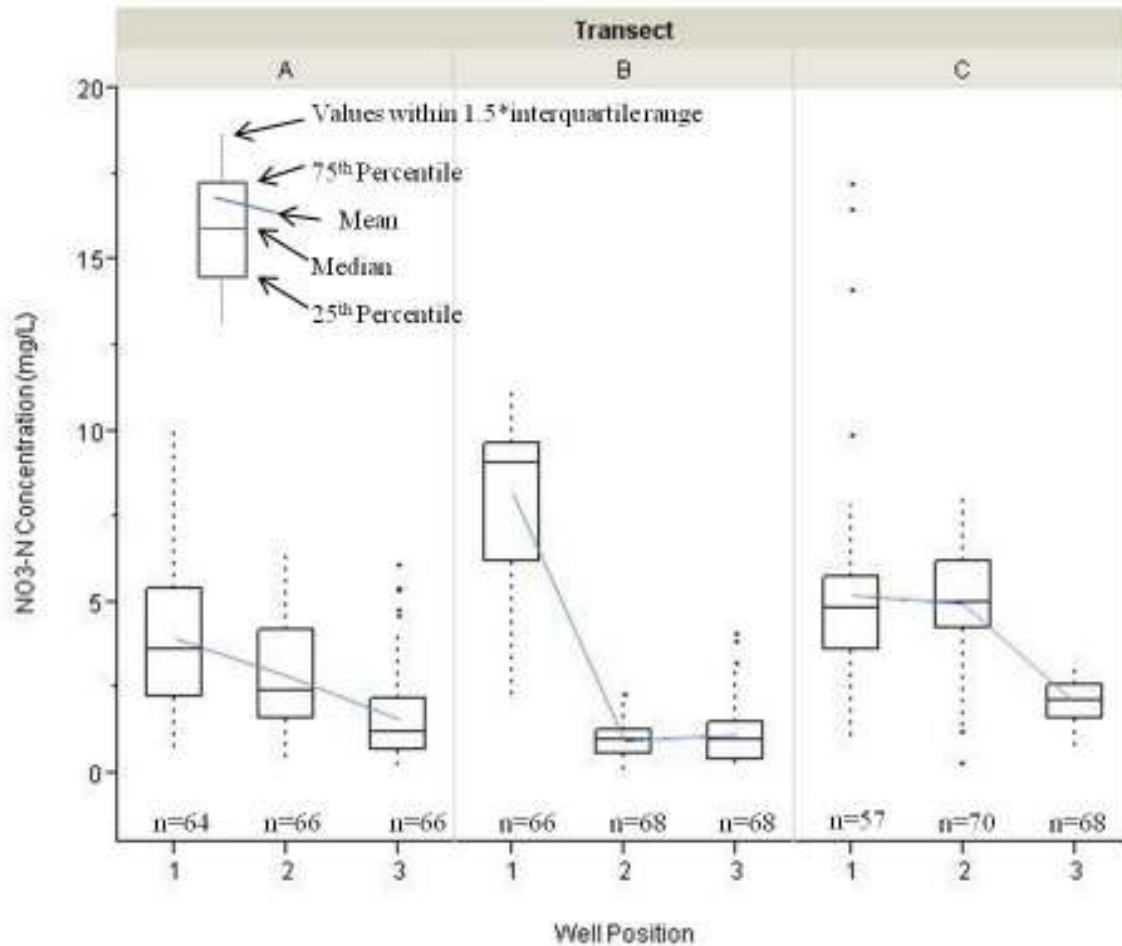


Figure 61. Block 3 deep (3.0 m depth) groundwater NO₃-N concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means at each well position.

Nitrate-nitrogen concentrations were also analyzed for any seasonal trends in incoming concentrations at the pasture edge. All groundwater samples in a season were averaged for each pasture edge groundwater depth. Deep and shallow groundwater NO₃-N concentrations were then graphed by season over the entire monitoring period as shown in

Figure 62. No strong seasonal trend could be identified, however, periods of slightly higher concentrations were found such as the spring of 2008 and fall of 2009.

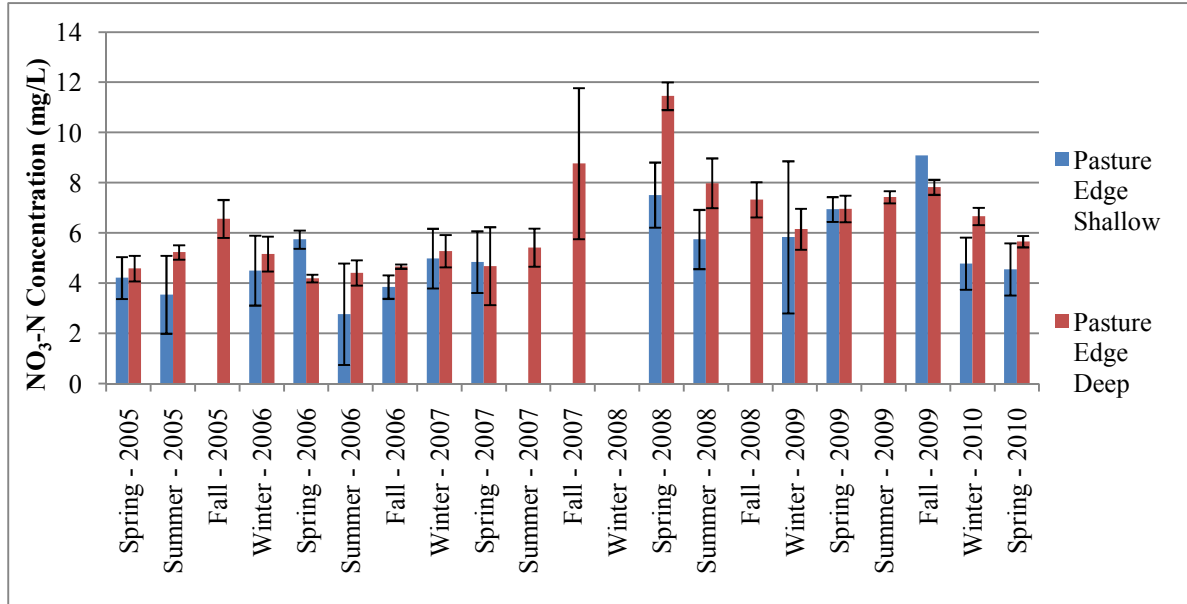


Figure 62. Block 2 mean groundwater NO₃-N seasonal concentrations over the monitoring period for shallow (1.5 m depth) and deep (3.0 m depth) groundwater at the pasture edge. Error bars represent standard deviations of individual seasonal mean concentrations

Table 15 shows the yearly NO₃-N loads per hectare of contributed area calculated for the shallow 1.5 m (5 ft) depth and deep 3.0 m (10 ft) groundwater over the monitoring period. The total combined load of deep and shallow groundwater decreased from pasture edge to stream edge in every monitoring year. Yearly total pasture edge NO₃-N loads ranged from 3.0 to 8.1 kg/ha/yr. A review of relevant literature found these values were on the lower end of ranges reported by Line et al (2000) and Beulac and Reckhow (1982). Both of these studies reported NO₃⁻ load export ranges of 6-36 kg/ha/yr and approximately 2-30 kg/ha/yr respectively. Some of this discrepancy could be because these studies measured

loads in streams at the outlet of the watershed rather than in groundwater like this study. Stream edge total loads were calculated to range between 0.6 and 2.2 kg/ha/yr. This corresponded to percent reductions in load between the pasture edge and stream edge groundwater of between 67% and 83%. A mean percent reduction of loads was calculated to be 74% or about 1.2 kg-N/ha removed each year.

At the pasture edge and stream edge, a larger load was calculated for deep groundwater in all of the monitoring years. This was likely because the measured saturated hydraulic conductivity was higher in the deep layer than in the shallow layer (6.0 cm/hr and 4.6 cm/hr respectively), so that a larger volume of water was able to flow through the deep soil layer during the monitoring period. Rainfall did not seem to have the same affect on the load that was found in Block 1. Load seemed to be more dependent on the large spikes in NO₃-N concentration that occasionally occurred as shown in Figure 62, for instance the large concentrations found in the spring and summer of 2008.

It should be noted that these loads calculations assume that no dilution of NO₃-N concentrations was occurring in the monitoring block and that any reductions in concentrations was due to biological removal.

Table 13. Block 3 NO₃-N loads for deep and shallow wells.

Year	Pasture Edge		Mid-Buffer		Stream Edge	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
2005	0.7	2.3	0.3	1.5	0.2	0.8
2006	1.3	3.0	0.3	2.1	0.1	1.0
2007	0.7	1.8	0.1	1.0	0.1	0.4
2008	2.4	5.7	0.1	1.7	0.5	0.9
2009	2.1	4.6	0.5	2.5	0.6	1.6
2010	1.4	2.8	0.3	0.6	0.3	0.9
Totals	8.6	20.2	1.8	9.3	1.9	5.6

Redox

Redox potentials were measured to determine if the anaerobic conditions associated with the denitrification process were occurring in the buffer and could support that observed reductions in NO₃-N concentrations were due to denitrification. Kralova et al (1992) and Bailey and Beauchamp (1973) found that denitrification was a major process at redox potentials below 200 mV. Bailey and Beauchamp also found that denitrification could occur at higher potentials, likely up to 400 mV, but that oxygen was simultaneously being utilized at potentials greater than 200 mV. Table 14 shows the percent of each year that each probe was below the water table, and the percent of sampling events each year that the mean redox potential was a) below +200 mV, when O₂ was likely depleted and NO₃⁻ was a primary electron acceptor, and b) below +350 mV, where both O₂ and NO₃⁻ were both being utilized as electron acceptors. It is important to note that the reported redox potentials are just small points meant to estimate soil redox potentials for the entire buffer. Other locations in the

buffer may have had either more positive or more negative potentials depending on localized conditions.

Table 14. Percent of each year Block 3 redox probes at the shallow (1.5 m depth) and deep (3.0 m depth) were below the water table and percent of sampling events each year that mean redox potentials were less than 200 mV or less than 350 mV.

Probe Location		2006 (n=6)	2007 (n=9)	2008 (n=7)	2009 (n=12)
Pasture Edge Shallow (1.5 m depth)	% saturated*	67%	30%	33%	36%
	<200mV	100%	56%	0%	50%
	<350mV	100%	67%	43%	67%
Pasture Edge Deep (3.0 m depth)	% saturated*	100%	66%	77%	82%
	<200mV	0%	100%	29%	42%
	<350mV	100%	100%	100%	100%
Mid-Buffer Shallow (1.5 m depth)	% saturated*	90%	37%	31%	29%
	<200mV	100%	78%	57%	58%
	<350mV	100%	100%	86%	83%
Mid-Buffer Deep (3.0 m depth)	% saturated*	100%	80%	54%	98%
	<200mV	100%	100%	100%	100%
	<350mV	100%	100%	100%	100%
Stream Edge Shallow (1.5 m depth)	% saturated*	100%	39%	32%	34%
	<200mV	100%	56%	43%	75%
	<350mV	100%	100%	100%	92%
Stream Edge Deep (3.0 m depth)	% saturated*	100%	76%	54%	100%
	<200mV	0%	56%	29%	25%
	<350mV	17%	89%	86%	100%

*Note: % saturated represents percentage of days soil surrounding the redox probe was saturated

Figure 63 shows the shallow and deep redox potential values for the pasture edge redox probes for the year 2009. Other years of the monitoring period can be found in

Appendix A. Shallow probes were placed at an elevation of about 61.5 m and deep probes were placed at an elevation of about 60.2 m.

Mean redox potentials for the shallow 1.5 m (5 ft) depth probe during the winter and spring months were relatively low compared to the rest of the year, likely because the probe was below the elevation of the water table during this portion of the year. As the water table lowered in elevation throughout the summer the mean redox potentials increased considerably. This was true for all of the monitoring years. Table 14 shows that the shallow probes were typically only inundated for 30% to 36% of the year, except in 2006, the year with the most rainfall in the monitoring period, when the probes were below the water table for about 67% of the year. The increasing trend in redox potentials began approximately when the water table fell below the elevation of the shallow probes. A maximum redox potential at the shallow depth of 537 mV was reached in late August, then potentials began to slightly decrease to about 378 mV in December. The percentage of sampling events each year that shallow probes were above the +200 mV threshold ranged widely between years, they were below the threshold for 100% of the year in 2006 and 0% of the year in 2008. Similarly, the percentage of sampling events below the +350 mV threshold ranged from 100% in 2006 to only 43% in 2008.

Pasture edge probes at the deep 3.0 m (10 ft) depth were below the elevation of the water table for a larger portion of each year and displayed a small decreasing trend in mean potentials from March to September. When the water table fell below the deep probe

elevation, usually during October or November, mean potentials began to increase up to a maximum mean of +339 mV. Table 14 shows the pasture edge deep probe was below the elevation of the water table for a majority of the sampling period. The number of sampling events where the mean potential for the deep probes was below the +200 mV threshold ranged from 0% to 100%. Interestingly, in 2006, the year with the most rainfall and highest overall water table, the mean potential was never below the +200 mV threshold. Closer inspection of the 2006 values showed that it was quite close, however, with mean potentials ranging from 203 mV to 279 mV. In all monitoring years the mean potential of the deep probes was never above +350mV.

Pasture edge soil redox means at both the shallow and deep groundwater depths showed varying degrees of potential for denitrification to occur depending on the year. However, the shallow depth was still below the +350 mV threshold for a majority of the monitoring period despite being below the water table much more rarely. The deep depth was more routinely below the water table and was never above the +350 mV threshold. This indicated that denitrification could have occurred in this area of the buffer during some parts of each year.

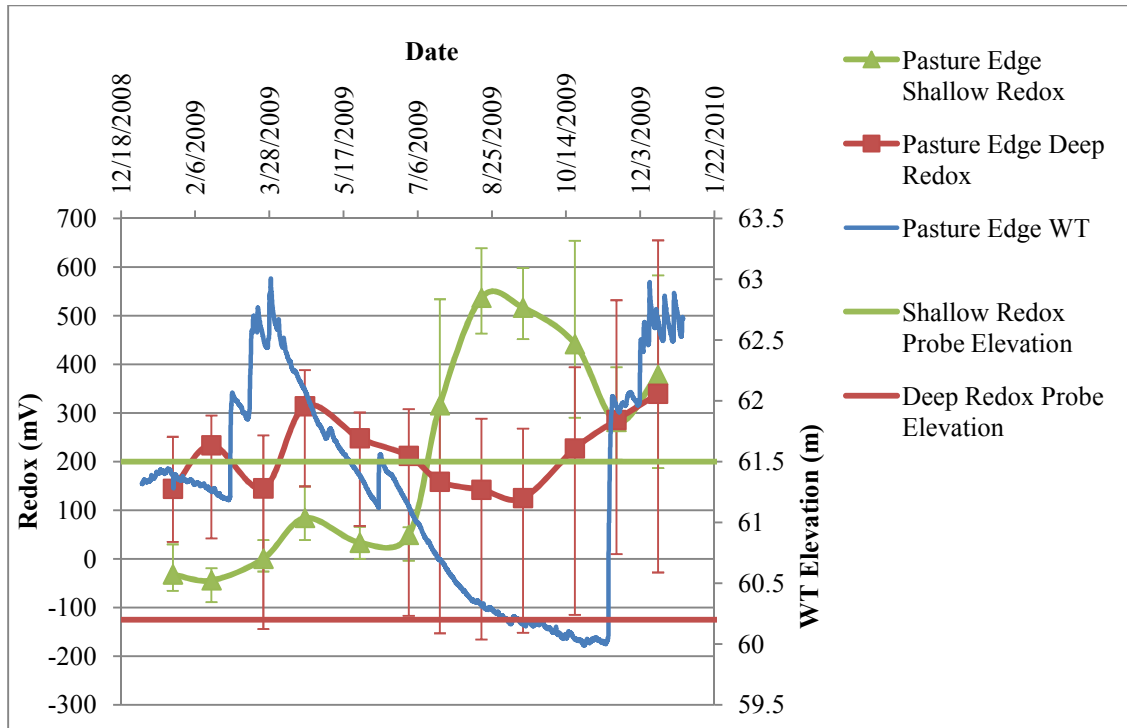


Figure 63. Block 3 mean pasture edge redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Figure 64 shows the shallow and deep mean redox potentials at the mid-buffer well position for 2009. A rough estimate of the water table was used in the figure because no water table loggers were installed at the mid-buffer position. The estimate was obtained by adding the difference in ground elevation between the mid-buffer and stream edge well positions (about 0.3 m (1.0 ft)) to the stream edge water table elevations that were logged in the monitoring block. This was likely a conservative estimate of the actual water table at the mid-buffer because the stream lowered the water table at the stream edge. Shallow redox probes were installed at an elevation of 61.0 m (200 ft). Table 14 shows that the probes were

never below the water table for a majority of the year, only between 29% and 37% of the year, except 2006, the year with the most rainfall, when the probes were inundated for 90% of the year. Generally, at the mid-buffer shallow 1.5 m (5 ft) depth the mean redox potentials were between -150 mV and +200 mV at the beginning of the year through the early spring. Then in the mid-summer, usually early July, mean potentials began an increasing trend. This increase corresponded with when the water table dropped below the elevation of the probes. This upward trend usually ended in October with a maximum yearly mean potential of at least +300 mV and in some years higher, except in 2006 when the high water tables kept the potentials below +200 mV. This was similar to the trend in potentials that was found in the pasture edge shallow redox potentials. Table 14 shows that shallow probes were below the +200 mV for a majority of all the monitoring years, ranging from 57% to 78% of each year, except in 2006 when all potentials were below the threshold. Similarly mean potentials were nearly always below the +350 mV threshold with values ranging between 83% and 100% of the sampling events each year.

Deep probes at the mid-buffer were placed at an elevation of 59.5 m (195 ft) and were below the elevation of the water table for a majority of every year, ranging from 54% to 100% as shown in Table 14. The redox potentials were very low at this depth; all of the years began with the mean potential below 0 mV and most years the mean potentials were never above 0 mV. Table 14 shows that mean potentials were never above the +200 mV threshold for any of the monitoring years.

This seemed to indicate that the potential for denitrification was high at the mid-buffer with a majority of all mean redox potentials below the +200 mV threshold. Potential for denitrification was likely higher at the 3.0 m (10 ft) groundwater depth as all of the mean redox potentials measured at that depth were below the +200 mV threshold.

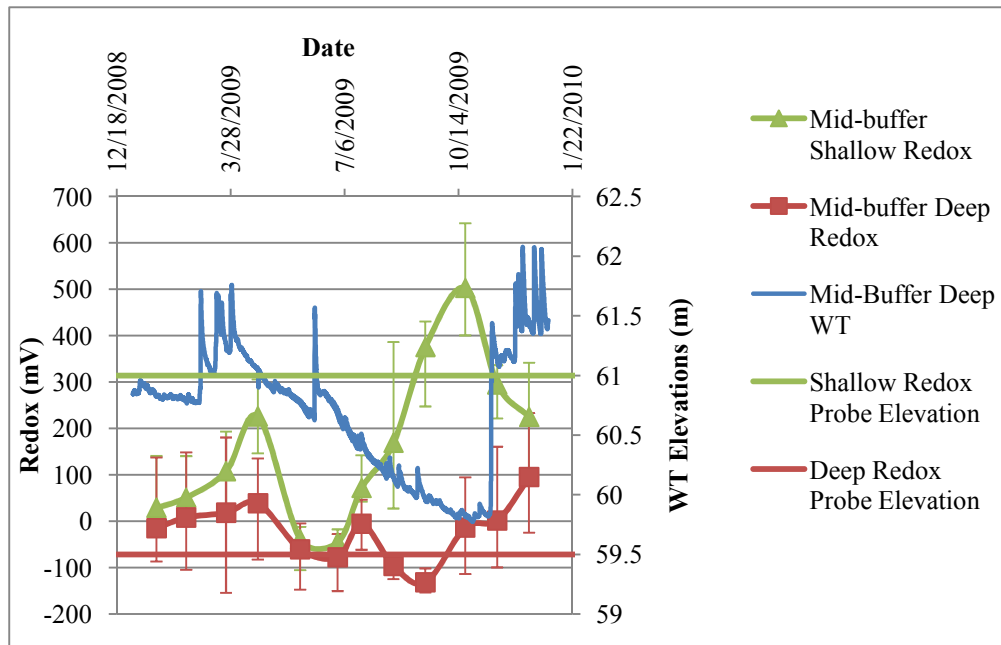


Figure 64. Block 3 mean mid-buffer redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Figure 65 shows the shallow 1.5 m (5 ft) depth and deep 3.0 m (10 ft) stream edge redox potentials and water table elevations for Block 3 in 2009. Shallow probes were placed at an elevation of 60.6 m (199 ft) and were only below the elevation of the water table between 32% and 39% of a year, except in 2006, the wettest year in the monitoring period, when the probes were always below the water table. Similar to the mid-buffer and pasture edge redox potentials, stream edge shallow mean potentials at the beginning of the year until

the spring were below +200 mV then increased during the drier summer and autumn months. The increasing trend usually began shortly after the water table dropped below the elevation of the shallow probes. The trend always increased to above the +200 mV threshold with a maximum mean potential of between +300 mV and +400 mV recorded in each monitoring year except 2006 when the mean potential was never above +200 mV. Table 14 shows that the number of samplings each year that were below the +200 mV threshold at the shallow 1.5 m (5 ft) depth ranged from 43% to 100% . All mean potentials were below the +350 mV threshold except one which occurred in 2009.

Deep probes were placed at an elevation of 59.4 m (195 ft) and were below the elevation of the water table for a majority of the monitoring period, however, mean potentials were only rarely below the +200 mV threshold. Mean potentials would begin the year with very high potentials, usually between +200 mV and +300 mV. Potentials would then begin to decrease after it had been inundated for a prolonged period and would fall below the +200 mV threshold usually during sometime in the summer or autumn months. None of the monitoring years had mean potentials that were less than 0 mV, except 2007, when a majority of the readings were found to be less than the +200mV threshold. The number of yearly sampling events that were below the +200 mV threshold ranged from 0% to 56% while the number that were below the +350 mV threshold ranged from 17% to 100%. Overall, the deep stream edge redox potentials were higher than the shallow probe at the same position. This was unexpected as redox conditions are generally thought to decrease with depth.

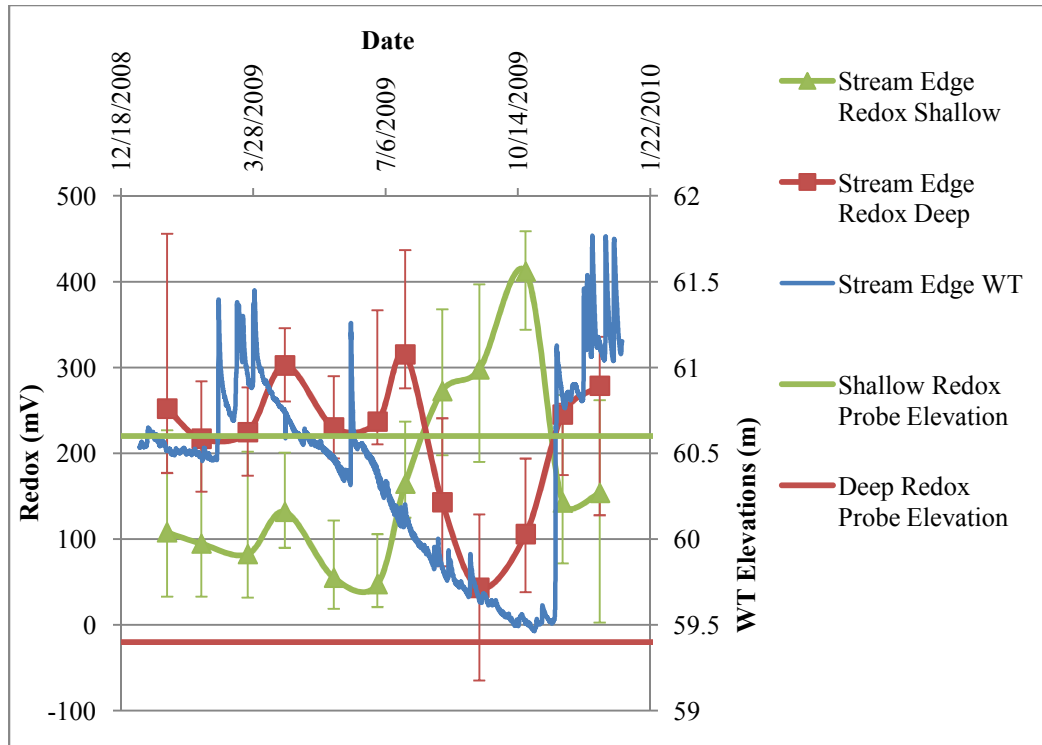


Figure 65. Block 3 mean stream edge redox potentials and water table elevations in 2009. Error bars represent the maximum and minimum readings recorded at each location during sampling events.

Groundwater Quality – Dissolved Organic Carbon (DOC)

To assess soil carbon availability for denitrification, groundwater DOC was sampled at the site from August 2008 to February 2010 on a bi-monthly basis. Figure 66 is a boxplot of Block 3 DOC concentrations and shows that median groundwater concentrations were similar throughout the site, ranging from 2.0 mg/L to 2.7 mg/L. Mean groundwater concentrations were also very similar to each other ranging from 3.0 mg/L to 4.8 mg/L. There was found to be no difference between well positions for deep and shallow depths (values ranged from $p = 0.1286$ to $p = 0.5967$). Figure 67 shows the seasonal concentrations of DOC, but a strong seasonal trend could not be detected during the 18 month collection

period. The figure does show that concentrations were highest during the summer of 2008 much lower during the following time periods and then slightly elevated again during the fall of 2009 and winter of 2010. The figure also shows that that DOC was evenly distributed in groundwater between the different areas of the buffer.

Mean DOC concentrations in Block 3 were on the lower side of the range that denitrification has been shown to occur by other researchers. Obenhuber and Lowrance (1991) found that a small amount of denitrification could occur with DOC concentrations of about 4 mg/L in laboratory microcosms and that the rate drastically increased when DOC concentration were increased to 10 mg/L. Similarly, Starr and Gillham (1993) found that significant denitrification was occurring in a sandy aquifer with DOC concentrations from about 5 mg/L to 10 mg/L while almost no denitrification could be identified in a sandy aquifer with 2 mg/L to 3 mg/L concentrations of DOC. While a majority of Block 3 DOC concentrations were on the lower side of the denitrification range, samples at all well positions were frequently measured with much higher concentrations, in some cases above 15 mg/L. This seemed to suggest that DOC concentrations in the buffer were sufficient for some denitrification to occur, but the process was likely limited by carbon for portions of the monitoring period.

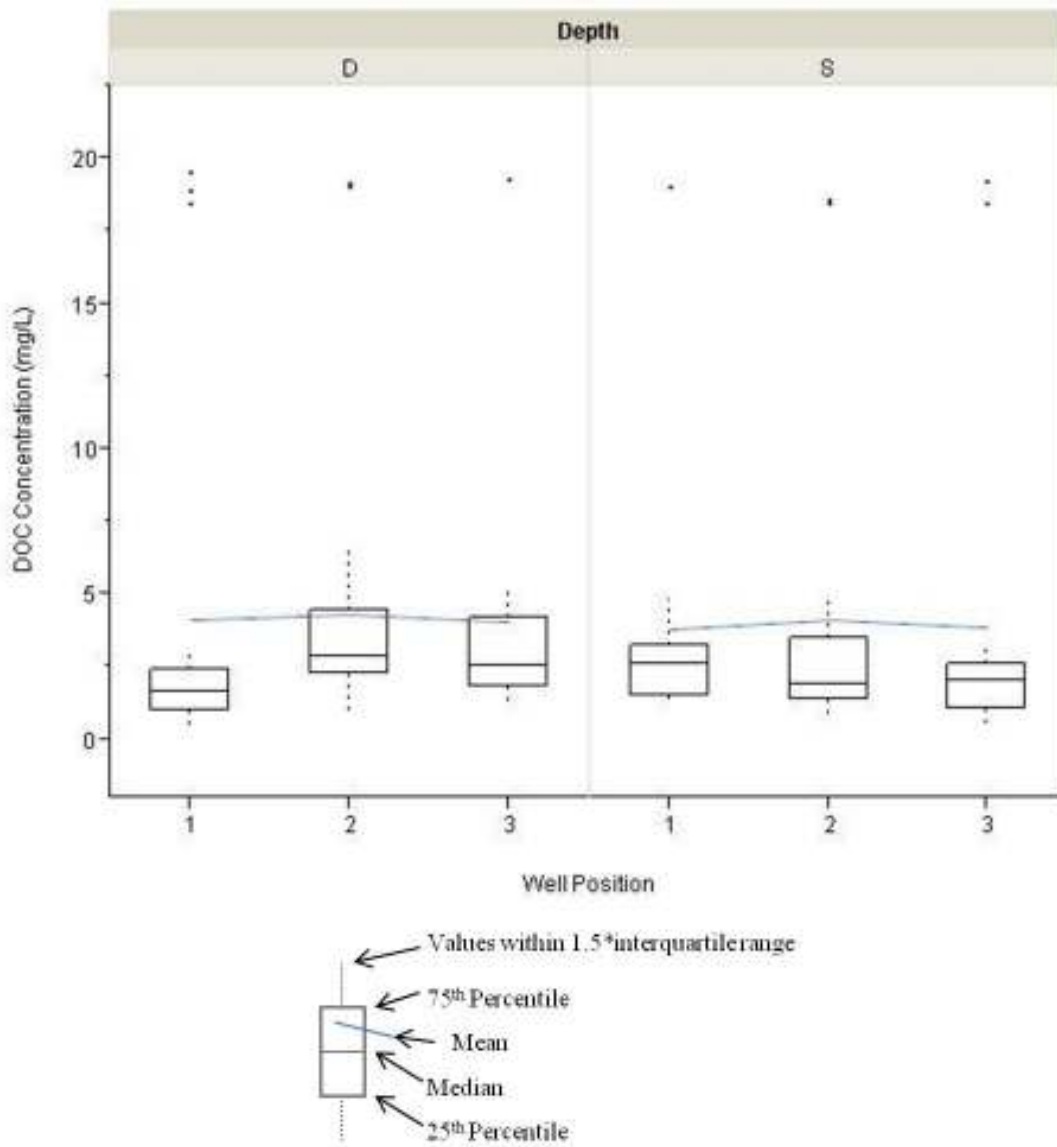


Figure 66. Block 3 DOC samples in deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position.

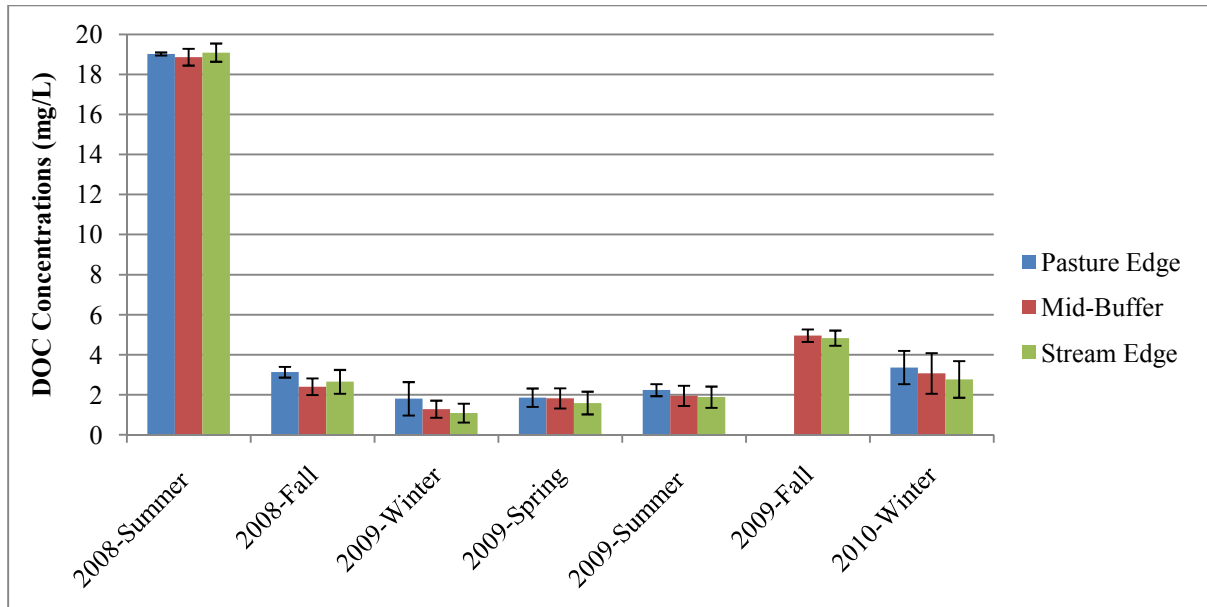


Figure 67. Block 3 Seasonal DOC Concentrations at different well positions. Error bars represent standard deviation of the value.

Redox potentials and groundwater DOC concentrations in Block 3 both indicated that the conditions required for denitrification to occur were present in the monitoring period. Reductions in $\text{NO}_3\text{-N}$ concentrations between the pasture edge and stream edge groundwater could potentially be attributed to denitrification.

Groundwater Quality – Nitrate/Chloride Ratios

Chloride concentrations were used to normalize $\text{NO}_3\text{-N}$ concentrations to determine if NO_3^- was actually being removed from the buffer, via vegetation uptake or denitrification, or if concentrations were being diluted by NO_3^- poor groundwater mixing with the surficial aquifer. The source of Cl^- in groundwater that was entering the buffer was the same as the source of $\text{NO}_3\text{-N}$, poultry litter that was broadcast on the upland pasture as fertilizer. $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios that decrease from the pasture edge to the stream edge are usually associated with

NO₃-N removal in the buffer, assuming a nearly constant Cl⁻ concentration. Ratios that do not change from the pasture edge to the stream edge are indicative of no NO₃-N removal, only dilution by a NO₃-N and Cl⁻ poor groundwater source. Ratios that increase across the buffer might indicate that either NO₃-N was increasing across the buffer while Cl⁻ was stable or NO₃-N concentrations were stable while Cl⁻ concentrations were decreasing. Both of these scenarios would require a source of NO₃-N originating inside the buffer.

Figure 68 shows the overall NO₃-N/Cl⁻ ratios for the shallow (1.5 m depth) and deep (3.0 m depth) groundwater for Block 3. Mean ratios decreased at both depths between the pasture edge and stream edge groundwater. Mean percent reductions in ratios between the pasture edge and stream edge were 70% for the shallow depth and 42% for the deep depth. All differences between groundwater locations at the shallow depth were found to be significantly different except the difference between the mid-buffer groundwater and the stream edge groundwater ($p=0.1645$). At the deep depth, no significant differences were found between the pasture edge and stream edge well positions ($p=0.0798$), the pasture edge and mid-buffer well positions ($p=0.0762$), and the mid-buffer and stream edge well positions ($p=0.9817$).

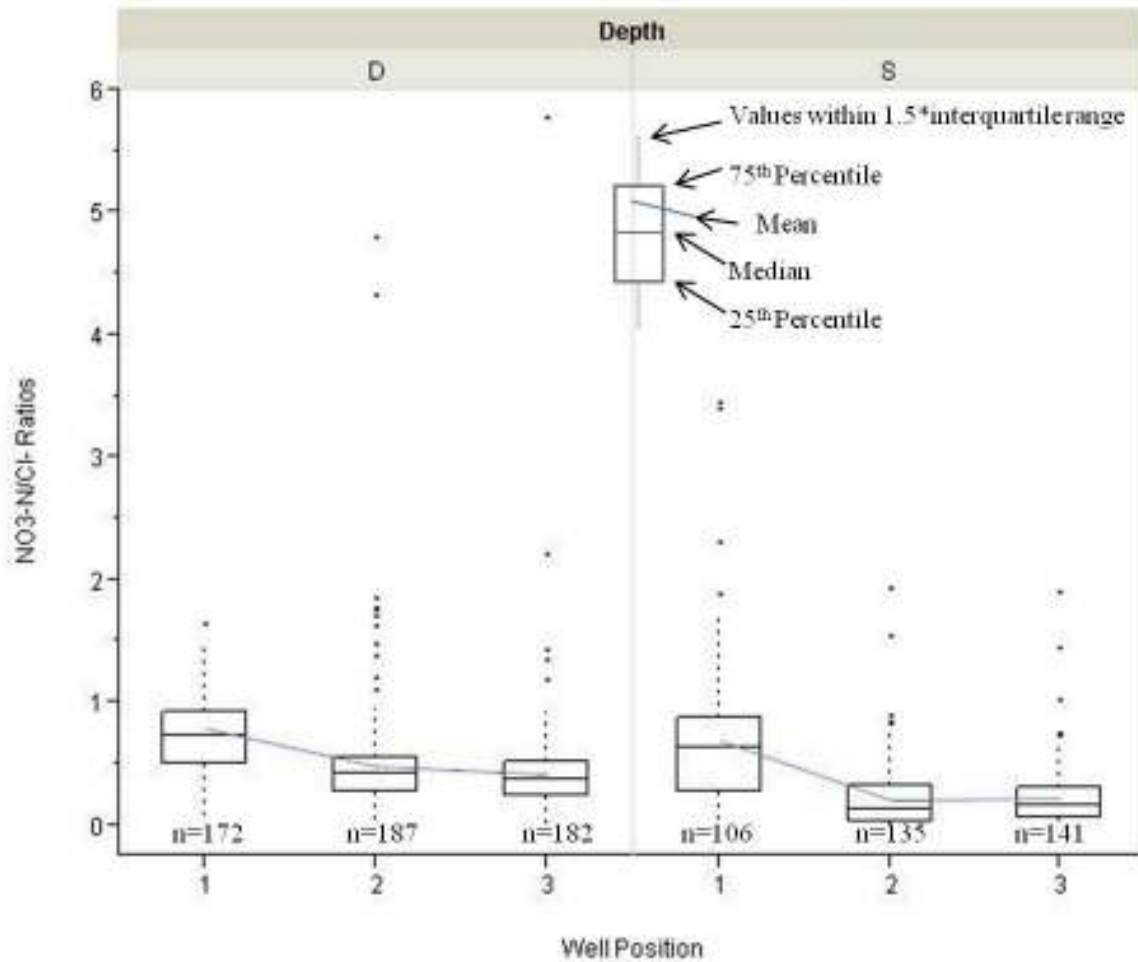


Figure 68. Block 2 shallow (S) (1.5 m depth) and deep (D) (3.0 m depth) groundwater $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent the trend between means at each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED – 16.0

Figure 69 shows $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios for the shallow depth. Ratios decrease from the pasture edge to the stream edge in every transect. All three transects show a majority of the decrease occurring between the pasture edge and mid-buffer well positions and very little

change between the mid-buffer well position and the stream edge well position. Percent reductions in ratios between the pasture edge and stream edge were also similar between all transects with transect A decreasing by 62%, transect B decreasing by 78%, and transect C decreasing 70%. This seemed to indicate that $\text{NO}_3\text{-N}$ may have been removed, by denitrification or vegetation uptake, between the pasture edge and mid-buffer well positions.

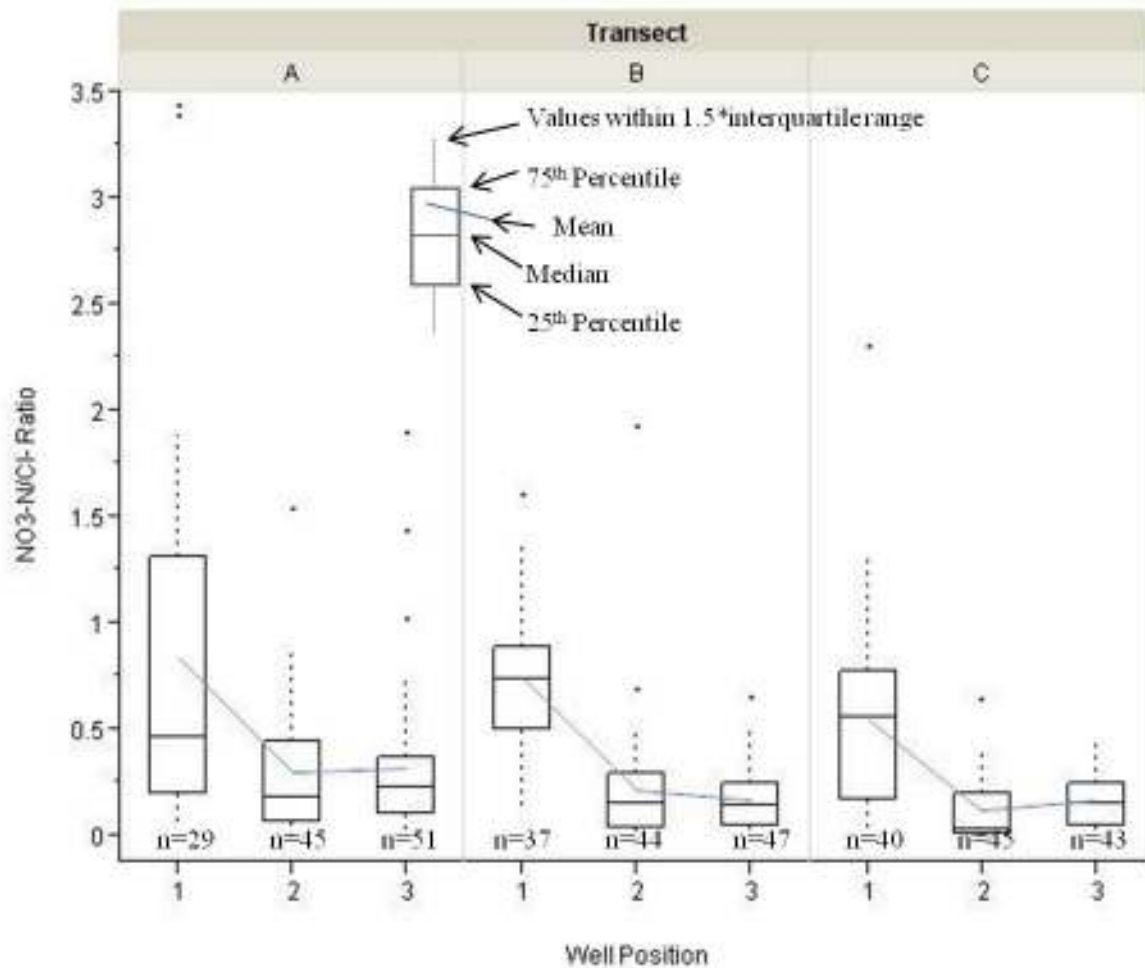


Figure 69. Block 3 shallow monitoring well NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position.

Figure 70 shows the NO₃-N/Cl⁻ ratios for the deep wells in Block 3. Transects A and C had very little difference between the ratios across the buffer and only decreased by 31% and 23% respectively between the pasture edge and stream edge wells. Transect B showed a much large decrease in ratios, 72%, from the pasture edge to the stream edge wells. Overall,

no significant difference was found between the different groundwater locations which indicated that no removal of NO₃-N occurred at this depth.

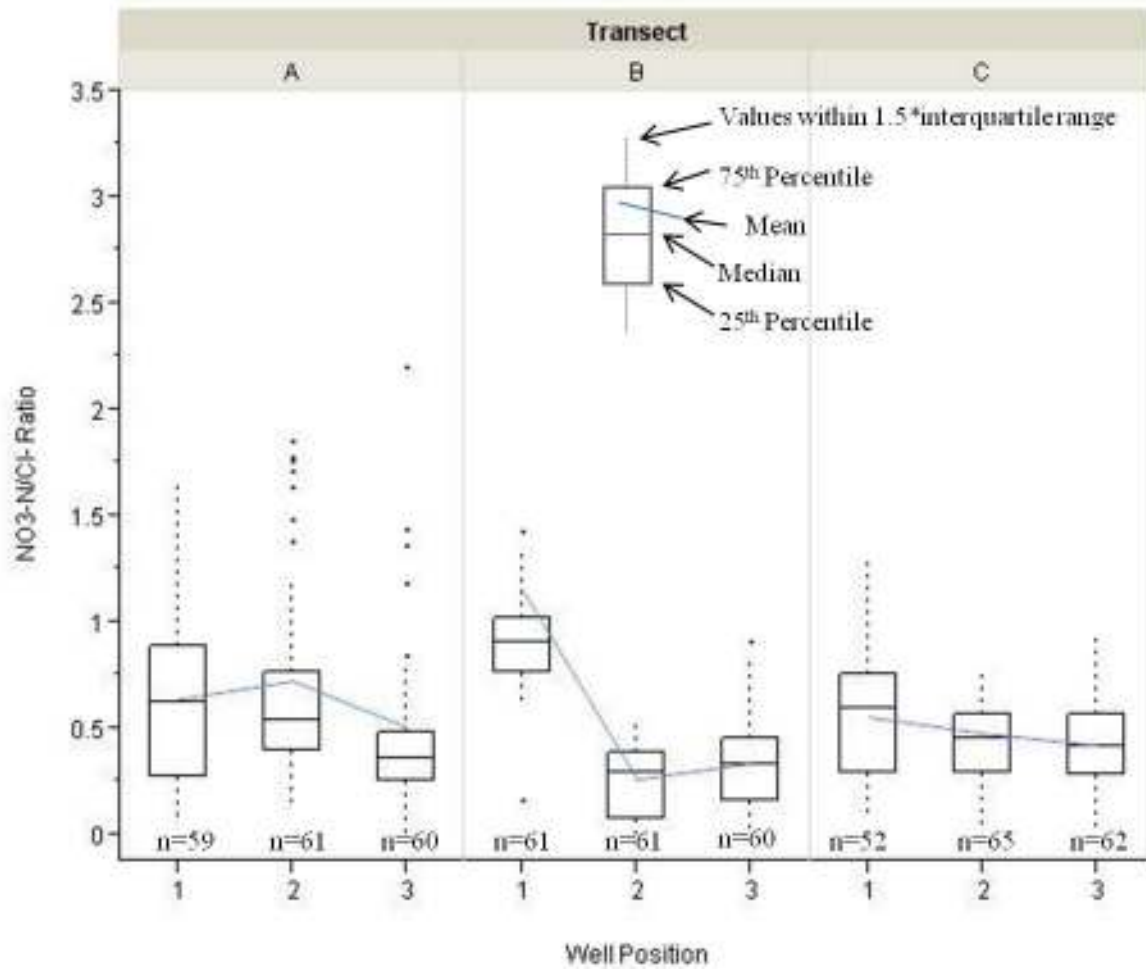


Figure 70. Block 3 deep (3.0 m depth) groundwater NO₃-N/Cl⁻ ratios for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between mean values for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED – 16.0, MBD - 4.8, 4.3, SED - 5.8),

Groundwater Quality – Chloride (Cl⁻)

If Cl⁻ concentrations were very similar among all well positions across the monitoring block, indicating that very little dilution due to groundwater mixing was occurring, then the NO₃-N/Cl⁻ ratios discussed above would indicate that NO₃-N was being removed by the buffer,

Figure 71 shows the Cl⁻ concentrations decreasing from the pasture edge to the stream edge for shallow and deep groundwater. Only the difference between pasture edge groundwater and stream edge groundwater was found to be significant for shallow groundwater, while the difference between pasture edge and mid-buffer groundwater ($p=0.2031$) and mid-buffer and stream edge groundwater ($p=0.0555$) was not found to be significant. The mean percent reduction in concentrations between the pasture edge and stream edge groundwater was 47% for the shallow depth. All differences between the well positions at the deep depth were found to be significant. The mean percent reduction between the pasture edge groundwater and the stream edge groundwater was found to be 48%, very similar to the shallow depth. The Cl⁻ data indicates that some groundwater mixing and subsequent dilution of concentrations likely was occurring Block 3.

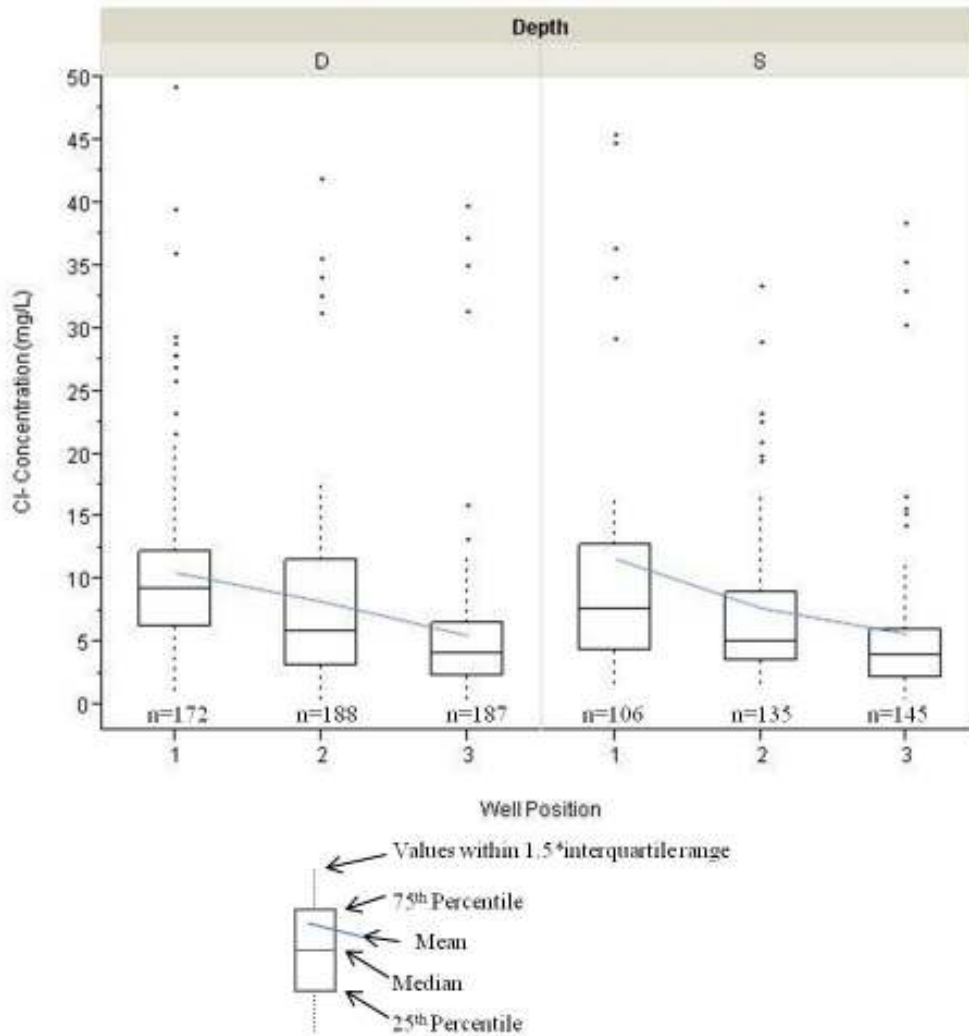


Figure 71. Block 3 deep (D) (3.0 m depth) and shallow (S) (1.5 m depth) groundwater Cl concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PED - 52.1 mg/L, MBD - 91.2 mg/L, SED - 83.1 mg/L, PES - 50.1 mg/L, 54.7mg/L, 65.1 mg/L, 66.1 mg/L, 79.2 mg/L, MBS - 55.5 mg/L, 91.2 mg/L, SES - 91.2 mg/L.

Figure 72, shows the shallow well depth Cl⁻ concentrations broken down by transect. All transects show the reduction in concentrations between the pasture edge and the stream edge that was found in Figure 71, above. However, in Transect C the decrease between the pasture edge and the mid-buffer was very small, which indicated that dilution may not have been as significant between these two wells.

Figure 73 shows the deep well depth Cl⁻ concentrations by transect. Again, all transects showed that the reductions in concentrations between the pasture edge and the stream edge found in Figure 71. Similar to the shallow groundwater, transect C was the only transect that did not decrease in concentration between the pasture edge and mid-buffer. There was actually a slight increase in mean Cl⁻ concentrations between these two wells from 12.5 mg/L at the pasture edge to 13.8 mg/L at the mid-buffer. Again this indicated that no dilution of concentrations may have been occurring between these two well positions.

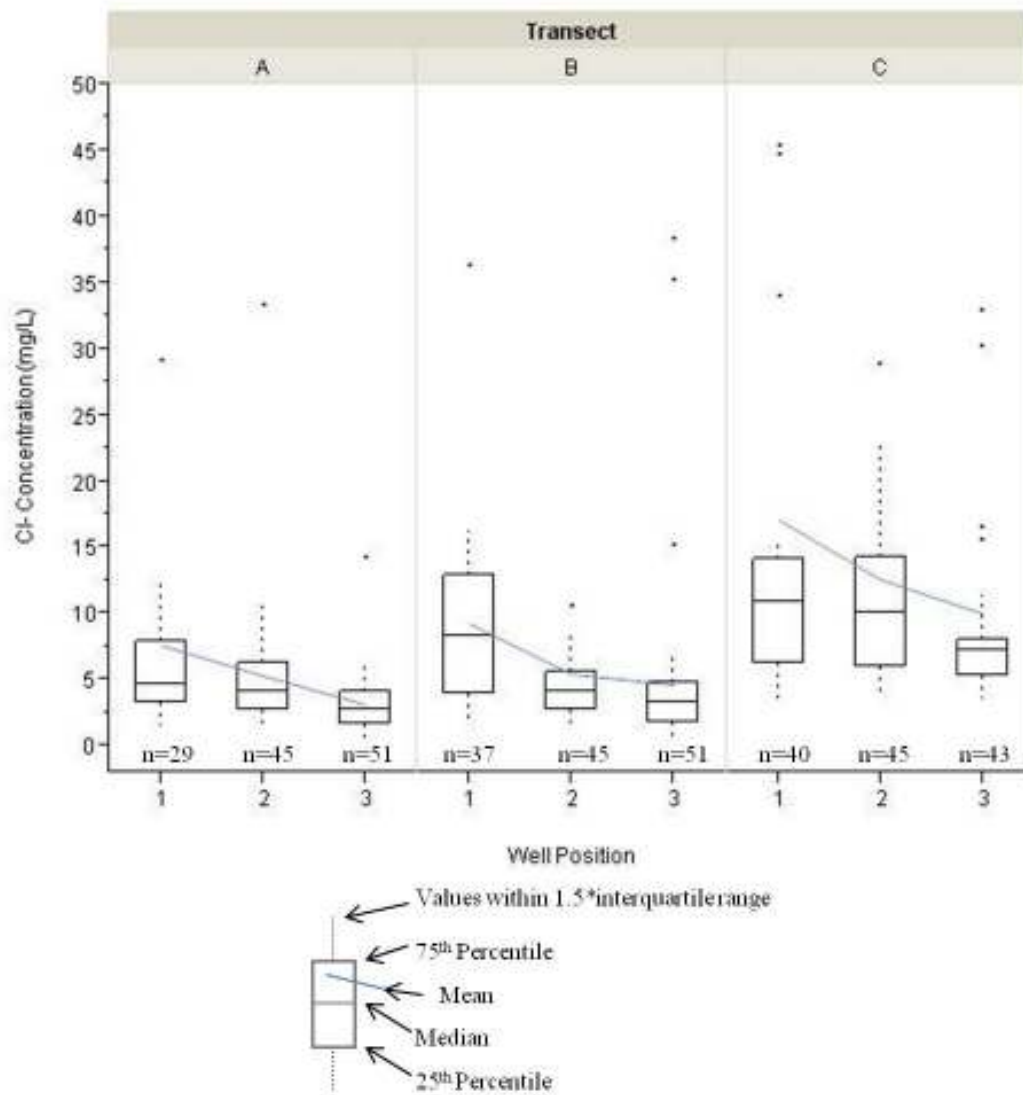


Figure 72. Block 3 shallow (1.5 m depth) groundwater Cl⁻ concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent means for each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: PES - 54.7 mg/L, 65.1 mg/L, 66.1 mg/L, 79.2 mg/L, 50.1 mg/L, MBS - 55.4 mg/L, 91.2 mg/L, SES - 91.2 mg/L.

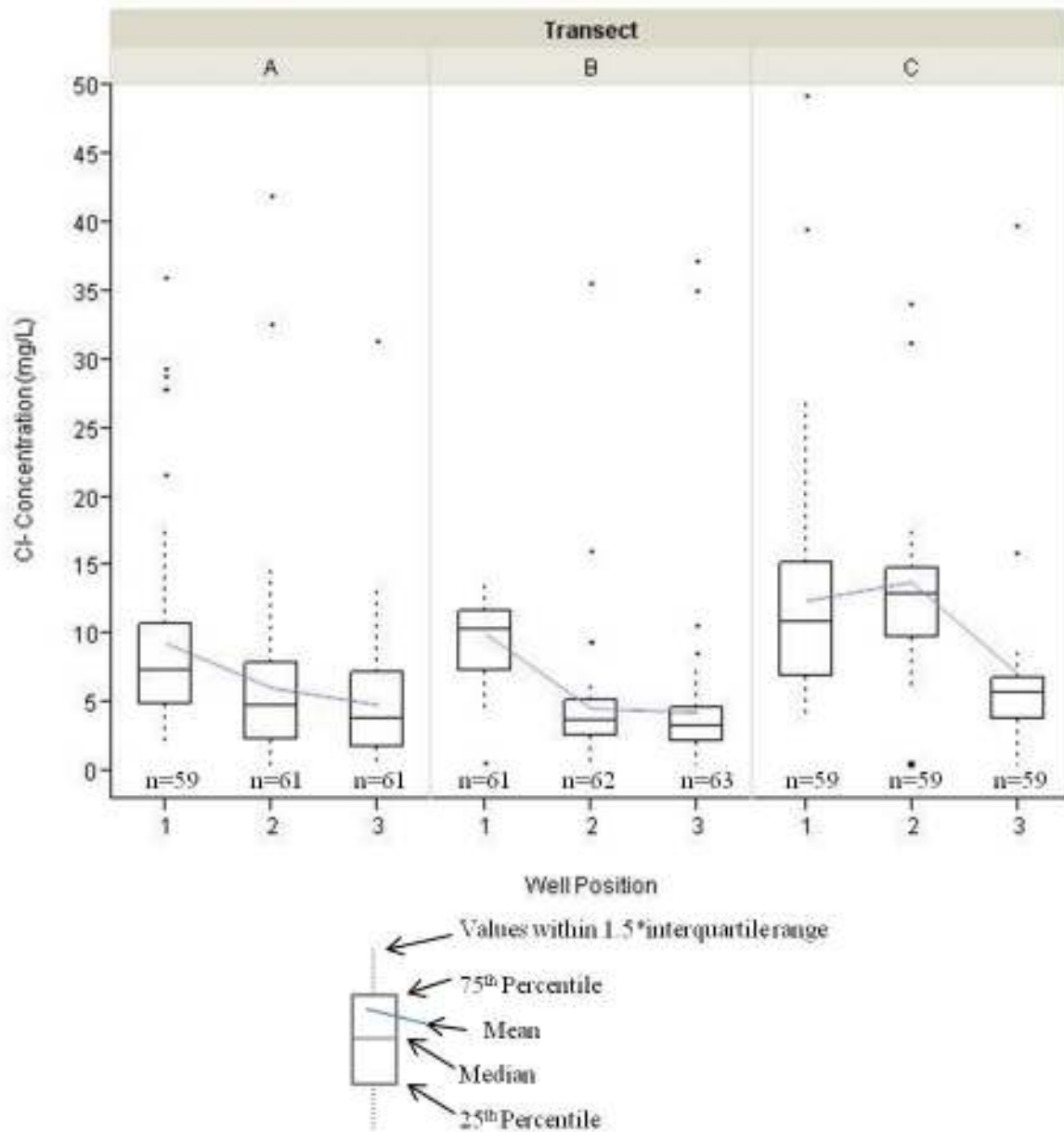


Figure 73. Block 3 deep (3.0 m depth) groundwater Cl⁻ concentrations for each transect at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3). Lines represent trends between means for each well position.

While decreasing $\text{NO}_3\text{-N}/\text{Cl}^-$ ratios indicated that NO_3^- removal occurred, decreasing Cl^- concentrations indicated that dilution also occurred. More investigation was needed so that a better conclusion could be drawn from the data. The mean of groundwater $\text{NO}_3\text{-N}$ and Cl^- concentrations for all pasture edge and stream edge 1.5 m (5 ft) and 3.0 m (10 ft) depth samples were calculated for each sampling date. The means were then plotted throughout the entire monitoring period as shown in Figure 74 for the shallow 1.5 m (5 ft) groundwater depth and Figure 75 for the deep 3.0 m (10 ft) groundwater depth.

Sampling concentrations for 1/23/2009 were removed from this analysis due to the high range Cl^- values and for better scaling in the figures. Chloride concentrations ranged from 14.3 mg/L to 91.2 mg/L on this sampling date.

Figure 74 shows that mean $\text{NO}_3\text{-N}$ concentrations decreased for a majority of the monitoring period between the pasture edge and stream edge groundwater at the 1.5 m (5 ft) depth. 39 of the 40 paired samples taken at the site showed a decrease in concentrations between the pasture edge and stream edge. 36 of those samples decreased by more than 2 mg/L, however, only 14 of the 40 paired samples decreased by more than 5 mg/L but none of the samples decreased by more than 10 mg/L. The mean and median percent reductions between pasture edge $\text{NO}_3\text{-N}$ concentrations and stream edge concentrations at the 1.5 m (5 ft) depth were 81% and 86% respectively. The largest reduction was 98% on 9/20/2006.

Figure 74 also shows that mean Cl^- concentrations decreased for a majority of the monitoring period between the pasture edge and stream edge groundwater at the 1.5 m (5 ft)

depth. 34 of the 40 paired samples decreased in concentration between the two locations, 24 of the 40 samples decreased by more than 2 mg/L. 17 of the 40 samples decreased by more than 5 mg/L, however, 12 of the 40 samples decreased by more than 10 mg/L. The mean and median percent reductions between the pasture edge and stream edge concentrations at the 1.5 m (5 ft) depth were 40% and 44% respectively. The largest decrease was 87% on 10/18/2006.

Overall Cl^- concentrations decreased in Block 3 shallow groundwater indicating that dilution by groundwater mixing with a Cl^- and $\text{NO}_3\text{-N}$ poor groundwater source was a major process in this monitoring block at the shallow 1.5 m (5ft) depth. Mean concentrations in the groundwater at 4.3 m (14 ft) below the ground surface at the stream edge were 2.6 mg/L and 7.3 mg/L for $\text{NO}_3\text{-N}$ and Cl^- respectively and may have been a major source of dilution. Different concentrations of $\text{NO}_3\text{-N}$ and Cl^- in the dilution source could have caused different rates of reductions in the concentrations in the surficial aquifer. However for this analysis dilution was assumed to have the same effect on both $\text{NO}_3\text{-N}$ and Cl^- concentrations in the upper aquifer where the shallow (1.5 m (5 ft) depth) and deep (3.0 m (10 ft) depth) groundwater was located. The greater change in $\text{NO}_3\text{-N}$ concentrations between the pasture edge groundwater and stream edge groundwater when compared to the change in Cl^- concentrations indicated that biological removal in excess of dilution could have occurred in the block. By subtracting the percent change in Cl^- concentrations from the percent change in $\text{NO}_3\text{-N}$ concentrations the role of biological removal in the buffer could be estimated as shown in Equation 10:

$$\Delta NO_3 - N\% - \Delta Cl^- \% = \Delta NO_3 - N\% \text{ due to biological removal} \quad [10]$$

This analysis was similar to one performed by Schoonover and Williard (2003). Table 23 in Appendix D shows the values that were calculated for each sampling date in the monitoring period. It should be noted that these estimations of biological removal represent the maximum removal that could be expected in the monitoring block, actual removals may have been lower.

The mean difference between the reduction in NO₃-N concentrations and the reduction in Cl⁻ concentrations between the pasture edge groundwater and stream edge groundwater was 38% and the median difference was 29%. This indicated that NO₃-N concentrations decreased between the pasture edge and the stream edge at a slightly higher rate than Cl⁻ concentrations decreased between the pasture edge and the stream edge. The largest calculated biological removal was 96% which occurred on 4/20/2005.

Figure 74 shows that near the end of 2007, Cl⁻ concentrations at the pasture edge may have been less than in previous years and seemed to more closely track with Cl⁻ concentrations at the stream edge. As was done in Block 1 and Block 2 the data was split into a pre-2008 and post-2008 sets and analyzed in the same manner that the entire data set was analyzed. Similar to Block 1 and 2, the post-2008 data had a larger biological removal of 47% reduction in NO₃-N concentrations while the pre-2008 data group had a biological removal of 32% reduction in NO₃-N concentrations.

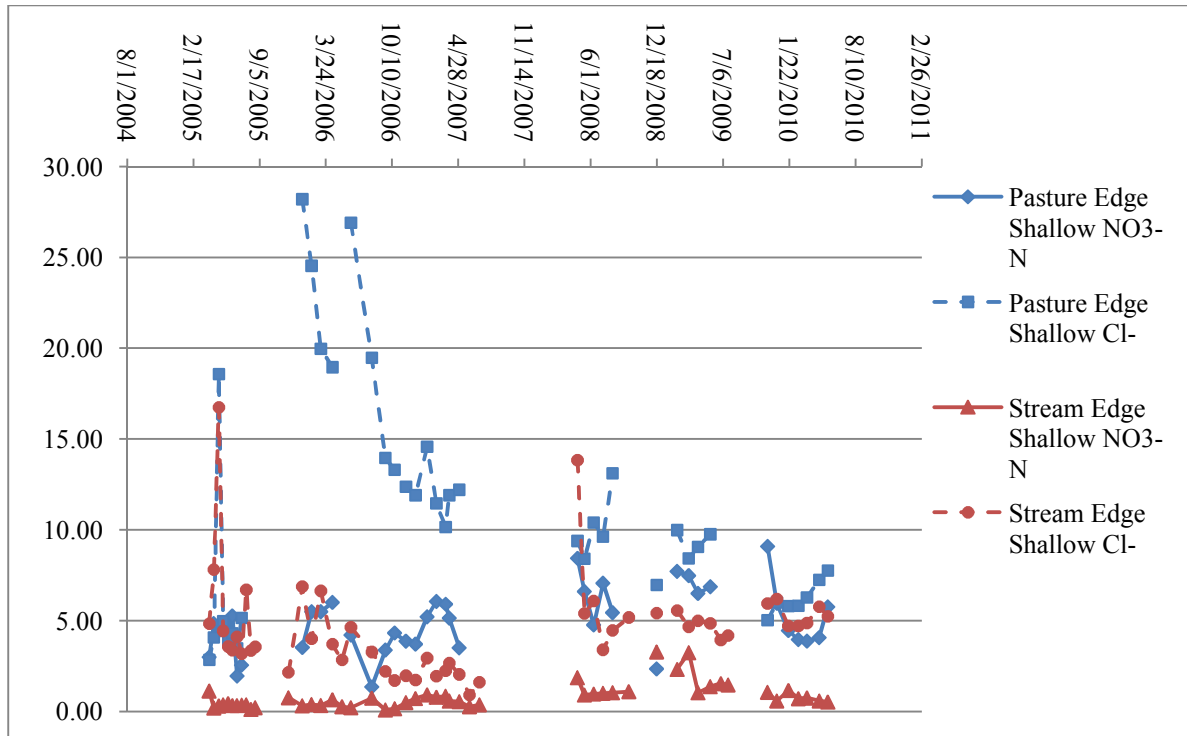


Figure 74. Block 3 mean pasture edge and stream edge NO₃-N and Cl⁻ concentrations in groundwater at the shallow depth (1.5 m) for each sampling date throughout the monitoring period. For clarity of scale samples taken on 1/23/2009 were removed from the graph.

A similar analysis was performed for the 3.0 m (10 ft) groundwater wells in Block 3. The mean of groundwater NO₃-N and Cl⁻ concentrations for all pasture edge 3.0 m (10ft) and stream edge 3.0 m (10 ft) wells were calculated for each sampling date. The means were then plotted throughout the entire monitoring period as shown in Figure 75. One sampling date, 1/23/2009, was removed because the extremely high Cl⁻ concentrations and so that the plot scale was reasonable. The figure shows that both NO₃-N and Cl⁻ concentrations in groundwater decrease between the pasture edge and the stream edge for a majority of the monitoring period. 60 of the 61 paired samples decreased between the pasture edge and

stream edge groundwater. 59 of the 61 paired samples decreased by more than 2 mg/L but only 12 decreased by more than 5 mg/L. The mean and median percent reductions in NO₃-N concentrations between the pasture edge groundwater and stream edge groundwater was 72% and 70% respectively. The largest percent reduction was 90% and occurred on 5/13/2008.

Figure 75 also shows that Cl⁻ concentrations also decreased for a majority of the monitoring period. 59 of the 61 paired samples decreased between the pasture edge and stream edge locations. 43 of the 61 samples decreased by more than 2 mg/L, 25 decreased by more than 5 mg/L and 8 decreased by more than 10 mg/L. The mean and median percent reductions in Cl⁻ concentrations between the pasture edge and stream edge groundwater was 48% and 42% respectively. The maximum decrease was 100% on 10/22/2008.

Again the analysis was performed to determine the amount that biological processes may have contributed to the decreases in NO₃-N concentration. Table 24 found in the Appendix D shows values calculated for each sampling date. The mean difference between the percent reductions in NO₃-N concentrations and the percent reductions in Cl⁻ concentrations was 25% and the median was 30%, while the maximum difference was 73% which occurred on 5/5/2005. These values were approximately the amount of reduction in NO₃-N concentrations that could be attributed to biological removal in the buffer at the deep depth. The data was again split into a pre-2008 and post-2008 groups and analyzed due to the slight changes between the two periods. The post-2008 period again had a higher biological removal of 38%. The estimated biological removal of the pre-2008 data set was a

17% reduction in NO₃-N that could be attributed to biological uptake. It is unknown why such a large discrepancy occurred between these two periods of the study.

These removals were less than what was been reported by previous researchers who calculated removals of between 75-99% (Altman and Parizek, 1995; Schoonover and Williard, 2003; Vellidis et al., 2003). However, the values are similar to those found by Clausen et al (2000) who reported a 35% N removal in the buffer groundwater, as well as, Dukes et al. (2002) and Snyder et al. (1998) who reported ranges of 28-84% and 16-70% respectively due to variability among buffers within each of their own studies. All of these studies accounted for dilution using some form of tracer except Snyder et al. (1998).

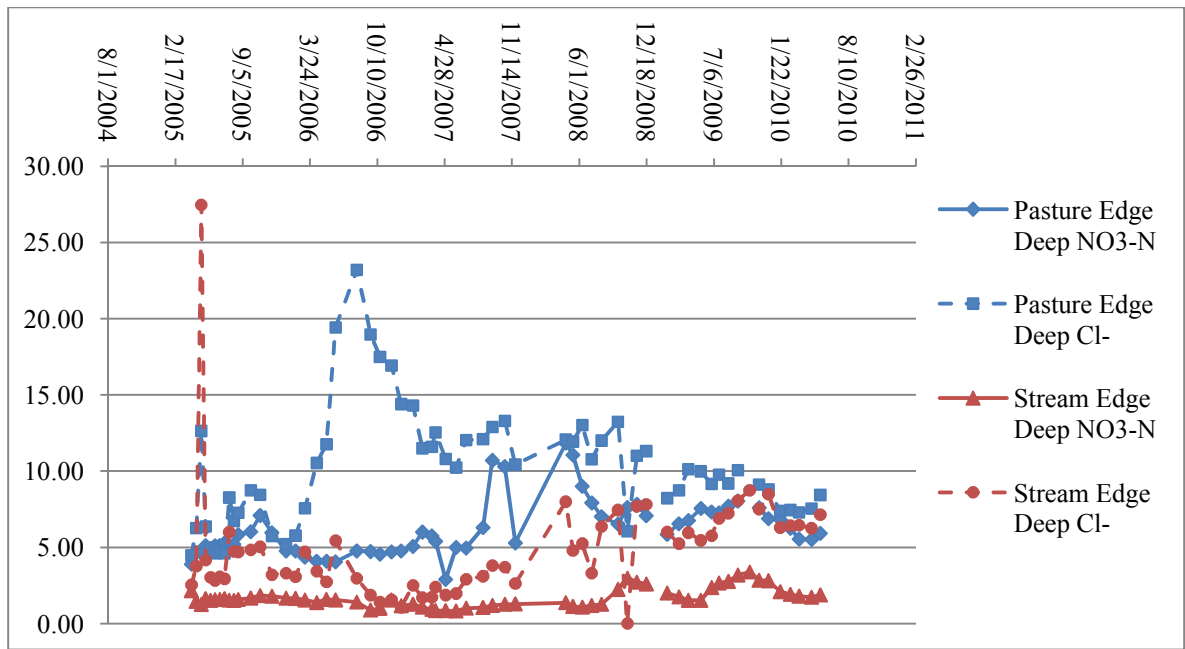


Figure 75 Block 3 mean pasture edge and stream edge NO₃-N and Cl⁻ concentrations in groundwater at the deep depth (3.0 m) for each sampling date throughout the monitoring period. For clarity of scale samples taken on 1/23/2009 were removed from the graph.

Groundwater Quality – Cations

Decreasing Cl⁻ concentrations seemed to indicate that significant groundwater mixing was occurring in the Block 3, however, more evidence was sought to confirm this conclusion. Cations were assessed at the pasture edge wells and stream edge wells in the surficial aquifer and in each deep aquifer well in an attempt to establish a difference in chemistry between the deep aquifer and surficial aquifer. If unique chemistries were found between the two aquifers then it would have been possible to conclude that the two aquifers were separated and very little dilution was taking place. Likewise, if the two aquifers had the

same chemistries throughout the buffer or at a particular location in the buffer then it might indicate that dilution was occurring in that area of the buffer.

Figure 76 shows the Na^+ concentrations in Block 3 based on groundwater elevation. Elevations above 65.2 m (213 ft) were considered a part of the surficial aquifer, which included shallow (1.5 m depth) and deep (3.0 m depth) groundwater, while elevations equal to or below 65.2 m (213 ft) were considered part of the deep aquifer. It is important to note that, unlike Blocks 1 and Block 2, no saprolitic soil layer was found in Block 3. The figure shows that there was very little difference between the mean concentrations at different elevations. Mean concentrations ranged between 2.0 mg/L and 8.0 mg/L.

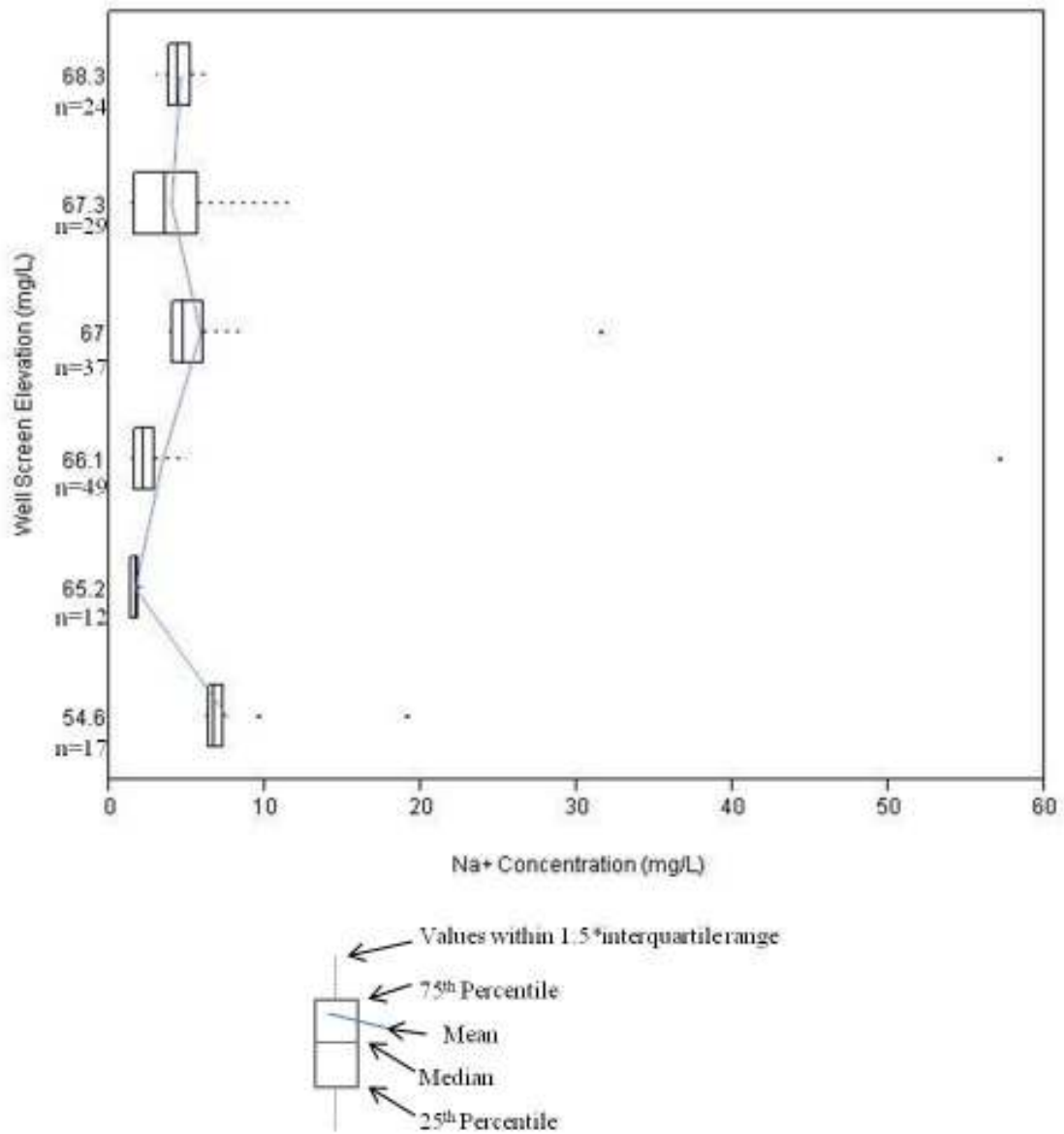


Figure 76. Block 3 Na⁺ Concentrations at various well depths below the ground surface. For clarity values were omitted from the Stream Edge Deep (value of 57.1 mg/L) and Pasture Edge Deep (value of 31.5 mg/L). Lines represent trends between means at different well positions

Figure 77 shows the Ca^{2+} concentrations at different elevations in Block 3. Again the only significant trend that was detected was that the deep aquifer groundwater that was located upgradient from the monitoring block had a much lower concentration compared to the concentrations of groundwater that was sampled within the monitoring block.

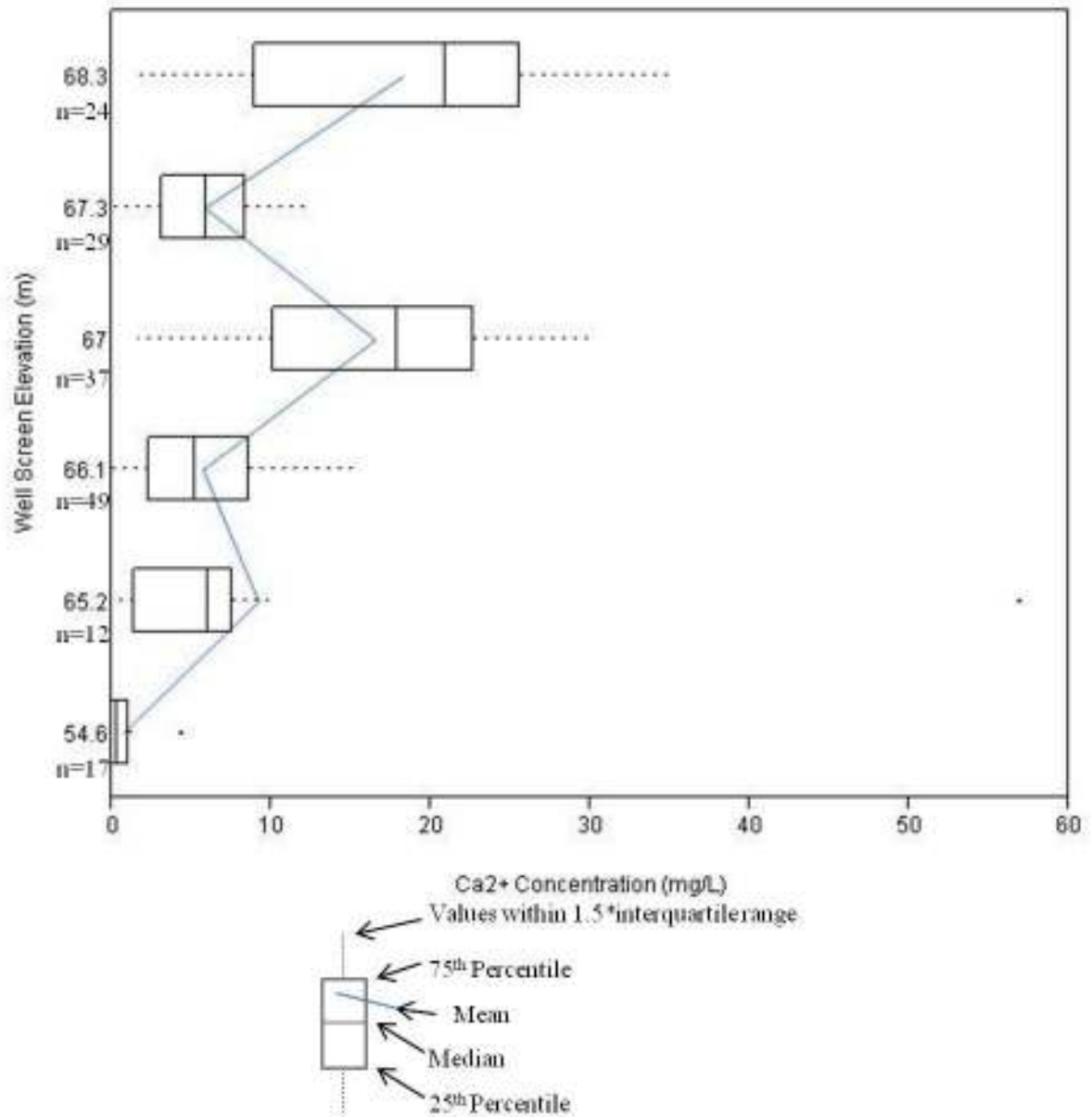


Figure 77. Block 3 Ca²⁺ Concentrations at various well depths below the ground surface. For clarity values were omitted from the Pasture Edge Deep (value of 56.9 mg/L). Lines represent trends between means at each well position.

Discussion and Conclusion

Significant reductions in $\text{NO}_3\text{-N}$ concentrations occurred in this monitoring block between the pasture edge groundwater and stream edge groundwater; a mean percent reduction in $\text{NO}_3\text{-N}$ of 82% for shallow 1.5 m (5 ft) groundwater and 71% for deep 3.0 m (10ft) deep groundwater over the monitoring period were recorded. Similarly, calculated $\text{NO}_3\text{-N}$ loads were reduced substantially between the pasture edge groundwater and stream edge groundwater in the buffer. Ideally this reduction in $\text{NO}_3\text{-N}$ would have been due to denitrification in the buffer which would have resulted in complete removal of the $\text{NO}_3\text{-N}$ from the system. There were indications that conditions were favorable for denitrification, however, there was also evidence that dilution of concentrations by groundwater mixing was partially responsible for the decreases in $\text{NO}_3\text{-N}$ concentrations.

Other measurements also indicated that conditions in the buffer were conducive for denitrification to occur throughout the monitoring period. Residence time for groundwater in the monitoring block was estimated to be slightly more than 2 years, which should have been adequate for denitrification to occur. At the deep depth, many of the redox measurements recorded in the buffer were below the +200 mV threshold where denitrification is thought to be a primary process and a majority of the measurements were below the +350 mV threshold where denitrification can occur. The shallow 1.5 m (5 ft) groundwater depth also recorded readings below both the +200 mV and +350 mV thresholds, but far less frequently than the deep probes. This was attributed to the water table dropping below the elevation of the shallow probes during dry periods creating aerobic conditions around the probe and making

denitrification less likely due to fewer O₂ depleted pore spaces. This likely limited the denitrification potential in the shallow groundwater.

Mean DOC concentrations in Block 2 were probably marginal for high rates of denitrification to occur and DOC concentrations may have been another of the limiting factors for denitrification in the buffer when concentrations were low. However, spikes of DOC to concentration of nearly 10 mg/L or above, where high rates of denitrification have been measured by other researchers (Obenhuber and Lowrance, 1991), occurred throughout the year.

However, these measurements did not account for groundwater mixing, changing flow volumes, or preferential flow paths that could have played a role in the decreasing NO₃-N concentrations. For this reasons, NO₃-N concentrations normalized by Cl⁻ concentrations were thought to be a better indicator of the fate of NO₃-N. Cl⁻ concentrations were found to significantly decrease between the pasture edge groundwater and stream edge groundwater for both the 1.5 m (5 ft) and 3.0 m (10 ft) depths, which indicated that not all of the reduction in NO₃-N concentrations was due to biological processes (denitrification or vegetation uptake) but a significant amount was also caused by dilution by a NO₃-N and Cl⁻ poor aquifer. Analysis of Cl⁻ samples on each sampling date indicated that these reductions occurred for a majority of the sampling period and that reductions in Cl⁻ concentrations were on average only slightly less than decreases in NO₃-N concentrations between the pasture edge groundwater and stream edge groundwater. At the 1.5 m (5ft) groundwater depth NO₃-

N concentrations decreased on average by 1.6 mg/L more than Cl⁻ concentrations. At the 3.0 m (10 ft) groundwater depth the difference was 1.2 mg/L. These differences were thought to be the maximum amount of reduction in NO₃-N concentrations that could be attributed to biological transformation, most likely by denitrification. The reduction of NO₃-N attributed to denitrification was calculated to be 32% and 20% for the 1.5 m (5 ft) and 3.0 m (10 ft) groundwater depths respectively.

It should be noted that Cl⁻ concentrations fluctuated throughout a large range at the pasture edge during the monitoring period. Often concentrations tracked very nearly with NO₃-N concentrations although not in all cases and the variability made interpretation of the data with high confidence difficult. Variability of Cl⁻ concentrations at the pasture edge were thought to be due to both the variability in the poultry litter source as well as possible uneven application of the litter to the pasture. This seemed to be a major drawback to the NO₃-N / Cl⁻ technique at this site. Despite these difficulties, data indicated that both dilution and denitrification of NO₃⁻ likely occurred in Block 3. Future work researching this monitoring block or other riparian buffers should take these findings into account and possibly use other techniques to account for dilution and denitrification.

While dilution due to groundwater mixing is not the preferred process of NO₃-N concentration reduction in riparian buffers, Block 3 may have still had an important role in improving water quality. The NO₃-N load entering the stream would have likely been greater if the pasture had extended all the way to the edge of the stream due to increased

surface runoff and an increase in the NO₃-N laden contributing area. The buffer acted as a barrier to surface runoff and a physical area where almost no additional NO₃-N would be added to the groundwater so that NO₃-N concentrations, from the pasture, could be diluted or transformed.

It is also important to note that further NO₃-N losses may have occurred as groundwater was being discharged through the hyporheic zone of the stream. Significant denitrification has been observed in other studies in this area of riparian buffers (Spruill, 2000). This would have increased the effectiveness of the buffer.

Other future work in this monitoring block could investigate the effect of the stream incision on the buffer effectiveness. As mentioned in the site description, the stream was incised between 1.2-1.5 m (4-5 ft) throughout Block 3, lowering the water table in the block especially along the stream edge. High water tables are considered an important characteristic of riparian buffers when NO₃⁻ reduction in groundwater is a major goal. In Block 3, higher water tables could provide anaerobic conditions for longer periods of each year and could possibly increase DOC concentrations in groundwater by leaching carbon from the upper horizons of the soil which could possibly translate to higher overall denitrification rates.

References

- Addy, K.L.; Gold, A.J.; Groffman, P.M.; Jacinthe, P.A. 1999. Ground water nitrate removal in subsoil of forested and mowed riparian buffer zones. *Journal of Environmental Quality* 28, 962-970.
- Ambus, Per and Lowrance, Richard. 1991. Comparison of denitrification in two riparian soils. *Soil Science Society of America Journal* 55(4), 994-997.
- Altman, S.J. and R.R. Parizek. 1995. Dilution of nonpoint-source nitrate in groundwater. *Journal of Environmental Quality* 24, 707-718.
- Aravena, R. and W.D. Robertson. 1998. Use of multiple isotope tracers to evaluate denitrification in ground water: Study of nitrate from a large-flux septic system plume. *Groundwater* 36 (6), 975-982.
- Bailey, L.D., and E.G. Beauchamp. 1973. Effects of moisture, added NO_3^- , and macerated roots on NO_3^- transformation and redox potential in surface and subsurface soils. *Canadian Journal of Soil Science* 53(2), 219-230.
- Beaulac, M.N., and K.H. Reckhow. 1982. An examination of land use – nutrient export relationships. *Water Resources Bulletin* 18 (6), 1013-1024.
- Böhlke, J.K. and Denver, J.M. 1995. Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland. *Water Resources Research* 31(9), 2319-2339.
- Christensen, T.H., Bjerg, P.L., Banwart, S.A., Jakobsen, R., Heron, G. Albrechtsen, H. 2000. Characterization of redox conditions in groundwater contaminant plumes. *Journal of Contaminant Hydrology* 25, 165-241.
- Clausen, J.C., Guillard, K., Sigmund, C.M., Dors, K. Martin. 2000. Water quality changes from riparian buffer restoration in Connecticut. *Journal of Environmental Quality* 29(6), 1751-1761.

- Dukes, M.D.; Evans, R.O.; Gilliam, J.W.; Kunickis, S.H. 2002. Effect of riparian buffer width and vegetation type on shallow groundwater quality in the middle coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers* 45(2), 327-336.
- Fieldler, S., M.J. Vepraskas, and J.L. Richardson. 2007. Soil redox potential: Importance, field measurements, and observations. *Advances in Agronomy* 94, 1-54.
- Gillham, R.W., R.C. Star, D.J. Miller. 1990. A Device for in-situ determination of geochemical transport parameters. *Groundwater* 28 (6). 858-862.
- Hill, A.R. 1996. Nitrate removal in stream riparian zones. *Journal of Environmental Quality* 25, 743-755.
- Hubbard, R.K.; Newton, G.L.; Davis, J.G.; Lowrance, R.; Vellidis, G.; Dove, C.R. 1998. Nitrogen assimilation by riparian buffer systems receiving swine lagoon wastewater. *Transactions of the American Society of Agricultural Engineers* 41(5), 1295-1304.
- Kilmer, V.J., J.W. Gilliam, J.F. Lutz, R.T. Joyce, and C.D. Eklund. 1974. Nutrient losses from fertilized grassed watersheds in Western North Carolina. *Journal of Environmental Quality* 3 (3), 214-219.
- Knowles, R., 1982. Denitrification. *Microbiological Reviews* 46 (1), 43-70.
- Kralova, M., P.H. Masscheleyn, C.W. Lindau, W.H. Patrick, Jr. 1992. Production of dinitrogen and nitrous oxide in soil suspensions as affected by redox potential. *Water, Air, and Soil Pollution* 61, 37-45.
- Larsen, D., R.W. Gentry, and D.K. Solomon. 2002. The geochemistry and mixing of leakage in a semi-confined aquifer at a municipal well field, Memphis, Tennessee, USA. *Applied Geochemistry* 18, 1043-1063.

- Line, D.E., W.A. Harman, G.D. Jennings, E.J. Thompson, and D.L. Osmond. 2000. Nonpoint-source pollutant load reductions associated with livestock exclusion. *Journal of Environmental Quality* 29, 1882-1890.
- Line, D.E., N.M. White, D.L. Osmond, G.D. Jennings, and C.B. Mojonnier. 2002. Pollutant export from various land uses in the upper Neuse River Basin. *Water Environment Research* 74 (1), 100-108.
- Martin, T.I.; Kaushik, N.K.; Trevors, J.T.; Whiteley, H.R. 1999. Review: Denitrification in temperate climate riparian zones. *Water, Air, and Soil Pollution* 111, 171-186.
- Mengis, M.; Schiff, S.L.; Harris, M.; English, M.C.; Aravena, R.; Elgood, R.J.; MacLean. 1999. Multiple geochemical and isotopic approaches for assessing ground water NO₃⁻ elimination in a riparian zone. *Ground Water* 37(3), 448-457.
- Natural Resource Conservation Service. 2008. Web soil survey: Halifax County, NC. Available at <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>. Accessed on April 15, 2009.
- Nicholson, F.A., B.J. Chambers, and K.A. Smith. 1996. Nutrient composition of poultry manures in England and Wales. *Bioresource Technology* 58, 279-284.
- Obenhuber, D.C. and R. Lowrance. 1991. Reduction of nitrate in aquifer microcosms by carbon additions. *Journal of Environmental Quality* 20(1), 255-258.
- Puckett, L.J. 2004. Hydrogeologic controls on the transport and fate of nitrate in ground water beneath riparian buffer zones: Results from thirteen studies across the United States. *Water Science and Technology* 49(3), 47-53.
- Rawls, W.J., D. Gimenez, and R. Grossman. 1998. Use of soil texture, bulk density, and slope of water retention curve to predict saturated hydraulic conductivity. *Transactions of the ASAE* 41 (4), 983-988.

- Saxton, K.E. and W.J. Rawls. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *United States Department of Agriculture and Washington State University*. Accessed at <http://hydrolab.arsusda.gov/SPAW/Index.htm>.
- Schoonover, Jon E.; Williard, Karl W.J. 2003. Ground water nitrate reduction in giant cane and forest riparian buffer zones. *Journal of the American Water Resources Association* 39(2), 347-354.
- Schwartz, F.W. and H. Zhang. 2003. *Fundamentals of Groundwater*. New York, N.Y.: John Wiley and Sons.
- Sóvik, A.K. and P.T. Mørkved. 2007. Nitrogen isotope fractionation as a tool for determining denitrification in constructed wetlands. *Water Science and Technology* 56 (3), 167-173.
- Snyder, N.J., S. Mostaghimi, D.F. Berry, R.B. Reneau, S. Hong, P.W. McClellan, and E.P. Smith. 1998. Impact of riparian forest buffers on agricultural nonpoint source pollution. *Journal of the American Water Resources Association* 34(2), 385-395.
- Spruill, Timothy B. 2000. Statistical evaluation of effects of riparian buffers on nitrate and ground water quality. *Journal of Environmental Quality* 29, 1523-1538.
- State Climate Office of North Carolina. Enfield Weather Station (ID# 312827). *North Carolina Climate Retrieval and Observations Network of the Southeast Database (NC CRONOS)*. Accessed at <http://www.nc-climate.ncsu.edu/services/request.php>.
- Starr, R.C. and R.W. Gillham. 1993. Denitrification and organic carbon availability in two aquifers. *Groundwater* 31(6), 934-947.
- Stefansson, A., S. Arnorsson, A.E. Sveinbjornsdottir. 2005. Redox reactions and potential in natural waters at disequilibrium. *Chemical Geology* 221, 289-311.
- United States Army Corps of Engineers. 1987. *Corps of Engineers Wetland Delineation Manual*. Accessed at <http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf>.

Van Beers, W.F.J. 1958. The auger hole method: A field measurement of the hydraulic conductivity of soil below the water table. *International Institute for Land Reclamation and Improvement*. 1-23.

Vellidis, G.; Lowrance, R.; Gay, P.; Hubbard, R.K. 2003. Nutrient transport in a restored riparian wetland. *Journal of Environmental Quality* 32, 711-726.

Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA-FS publication No. NA-PR-07-91. Radnor, Pa.: USDA-FS. Accessed at http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm.

Wafer, C.C., R.J. Barrett, and D.L. Osmond. 2004. Construction of platinum-tipped redox probes for determining soil redox potential. *Journal of Environmental Quality* 33 (6), 2375-2379.

Zublena, J.P., J.C. Barker, T.A. Carter. 1996. Poultry manure as a Fertilizer source. *North Carolina Cooperative Extension Service*. Pub. No. AG-439-5. Accessed at: http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag439_5.html

Chapter 5: OVERALL BUFFER COMPARISON ACROSS ALL MONITORING BLOCKS

Introduction

Riparian buffers have been shown to be variably effective at reducing sediment, pesticide and nutrients originating from agricultural lands (Lowrance et al., 1997). This seems especially true of nitrogen, one of the more heavily studied pollutants. Previous studies have shown that buffers can reduce NO_3^- concentrations in groundwater by as much as 75-99% (Altman and Parizek, 1995; Schoonover and Williard, 2003; Vellidis et al., 2003). However, not all buffers are this effective; Clausen et al (2000) found a nitrogen concentration reduction of only 35% in the buffer groundwater. Dukes et al. (2002) and Snyder et al. (1998) reported ranges of 28-84% and 16-70% respectively due to variability among buffers within each of their own studies. Site hydrology and carbon availability seem to be the two most widely discussed factors that can affect biological removal rates in the riparian setting

As was mentioned in Chapter 1, high carbon soils and high water tables are aspects of many riparian buffers that likely increase the potential for biological removal, specifically denitrification, to occur. It should follow that spatial and temporal differences in carbon availability and hydrology within the buffer could also lead to differences in in-situ denitrification rates. Gold et al. (1998) found that denitrification rates were higher around localized areas of high carbon concentration. These high carbon areas created “hotspots” of elevated denitrification throughout the buffer. Areas with little carbon showed very little or

no denitrification. Changes in hydrology throughout the year can also contribute to the variability in denitrification rates. Denitrification can only occur in those areas of the buffer where the soil is saturated for an extended period so that soil conditions become anaerobic or anoxic. The water table depth at the site is the major factor controlling soil moisture (Pinay et al., 1993) and water tables usually fluctuate due to seasonal variations in rainfall as well as changing evapotranspiration rates of vegetation in the buffer. Localized topography of a buffer might also cause the water table to be closer to the ground surface in certain parts of the buffer. Groundwater flow paths through buffers may also change due to these seasonal variations. Vellidis et al. (2003) also found that preferential flow paths of groundwater due to heterogeneous soils in riparian areas could circumvent potential denitrification areas, creating additional variability in observed rates.

The three monitoring blocks in this study were compared to assess if any major differences in the effectiveness of the buffer occurred throughout the monitoring period. Differences between the monitoring blocks could indicate the factors most important in controlling removal rates.

Materials and Methods

Site Description

Three monitoring blocks were selected within the CREP enrolled buffer for analysis and were positioned at different elevations within the buffer. Block 1 was the most downstream monitoring block and was positioned at the lower elevations in the buffer.

Block 2 was located at about the middle of the buffer and was between Block 1 and Block 3 in elevation. Block 3 was positioned near the beginning of the stream reach and was the highest monitoring block in elevation. Figure 78 shows an aerial view of the buffer and the approximate positioning of the 3 monitoring blocks in the buffer.

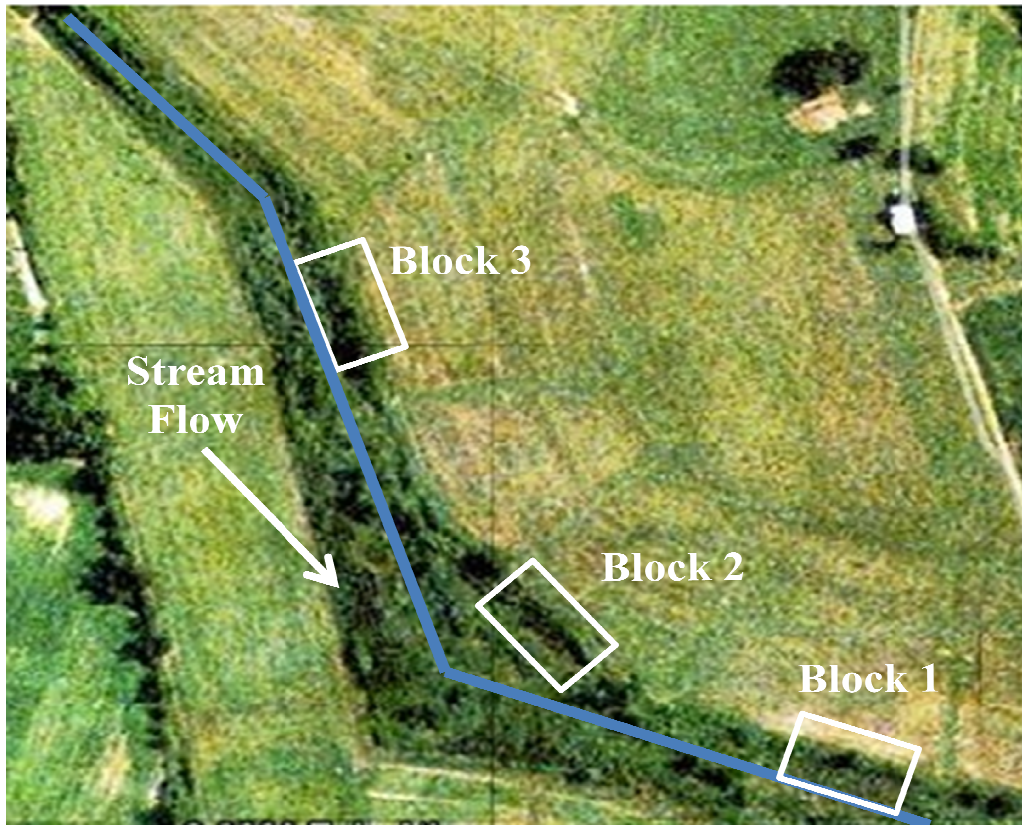


Figure 78. Site aerial view and monitoring block locations

The buffer was established and planted in 1999 and was planted according to the 3-zone design recommended by the USDA (Welsch, 1991). Zone 1 was adjacent to the stream and averaged about 12 m (40 ft) wide. Its primary vegetation was Northern Red Oak (*Quercus rubra*) which was planted at the site during the establishment of the buffer.

Colonizers included American Sweet Gum (*Liquidambar styraciflua*), fescue (*Festuca arundinaceae*), roundleaf greenbrier (*Smilax rotundifolia* L.), and the invasive Japanese Stilt grass (*Microstegium vimineum*). Zone 2 was planted with Loblolly Pine (*Pinus taeda*) and extended 21 m (70 ft) upslope from Zone 1. Zone 3 encompassed about 12 m (40 ft) between the pasture edge and Zone 2 and was planted with Switchgrass (*Panicum virgatum*) but fescue was also present.

The NO_3^- source at the site was broadcast poultry litter, which was applied to the upland pasture at a rate of about 41 kg-N/ha each year and was the same for all of the blocks. Soil surveys indicated that soils were the same in the buffer, a Goldsboro fine sandy loam (NRCS, 2008). Field verification found that the soils in Block 1 and Block 2 were similar consisting of sandy soil layers above a dense silty, saprolitic soil layer that occurred at about 3.7 m (12 ft). Rounded gravels in the upper layers indicated that the soils were likely alluvial. Block 3 had slightly different soils from the other monitoring blocks. The layers consisted mostly of very sandy layers, also with some gravels, however no saprolitic soil layer was found within 4.3 m (14 ft) of the ground surface. The instrumentation and monitoring layout of each monitoring block was also nearly identical. More detailed descriptions and schematics of each monitoring block can be found in Chapter 2 – 4 for each block. Plots in this chapter may have select water quality data removed to improve clarity. The location of the removed data will be noted in the caption under each graph using the following method: PE denotes pasture edge (well position 1), MB denotes the mid-buffer (well position 2), and SE denotes the stream edge (well position 3).

Statistical Methods

Statistical analysis was performed to determine if there were differences between the groundwater constituents at different well positions between the different monitoring blocks. The “proc mixed” procedure was used in SAS 9.1® (SAS Institute, Cary, NC) with block and well position used as the fixed effect and transect and transect*well position as random effects. The natural log of NO₃-N, Cl⁻, DOC concentrations and NO₃-N/Cl⁻ ratios were analyzed individually as response variables. The log was applied due to not normal distribution of residuals. Mean separation was tested at the $\alpha = 0.05$ significance level.

Results

Overall Summary of Results

Several of the parameters measured in each monitoring block as well as the mean removals of NO₃-N and estimated removal by biological processes are shown in Table 15. Detailed comparisons of some of the parameters will be presented in the following sections. Shallow 1.5 m (5 ft) depth and deep 3.0 m (10 ft) depth well water quality data was similar so data from each depth was lumped by well position for this analysis.

Table 15. Comparison of physical attributes and NO₃-N reductions in each Block

Parameter	Block 1	Block 2	Block 3
Contributing Area	2.5 ha	3.5 ha	3.5 ha
Upland Slope	0.045 m/m	0.047 m/m	0.036 m/m
Elevation of Pasture/Buffer Interface (Pasture Edge)	60.5 m	61.0 m	63.0 m
Elevation of Buffer/Stream Interface (Stream Edge)	58.2 m	59.5 m	62.1 m
Depth to Restrictive Layer	3.0 m	3.7 m	N/A
Stream Incision	1.2 - 1.5 m	1.1 - 1.4 m	1.2 - 1.8 m
Composite Saturated Hydraulic Conductivity	1.2 cm/hr	1.4 cm/hr	5.3 cm/hr
Mean Groundwater Gradient	0.026 m/m	0.016 m/m	0.024 m/m
Approximate Residence Time of Groundwater in the buffer	10.7 yrs	10.7 yrs	2.2 yrs
Percentage of Monitoring Period that Water Table was less than 60 cm below the ground surface at the stream edge	34%	17%	1%
Percentage of Redox Measurements below +200 mV	45%	57%	60%
Percentage of Redox Measurements below +350 mV	88%	78%	90%
Mean DOC Concentration	5.7 mg/L _a	4.5 mg/L _a	4.1 mg/L _a
Mean NO ₃ -N Concentration Entering Buffer	12.9 mg/L _b	7.2 mg/L _c	5.2 mg/L _c
Mean NO ₃ -N Concentration Leaving Buffer	1.1 mg/L _d	1.7 mg/L _e	1.3 mg/L _e
Mean Reduction in NO ₃ -N concentration	92%	76%	77%
Mean Reduction in Cl ⁻ Concentration	63%	65%	48%
Mean Maximum NO ₃ -N Reduction due to Biological Processes (denitrification)	40%	17%	32%

*Cells with different lower case letters represent significantly different values

Hydrology

The water table measured in each monitoring block exhibited the same general trend in each year of the monitoring period. Water tables were high during the winter and early spring months, generally declining during the late spring and summer months, except during large rain events, with the lowest elevations occurring in October or early November, and then increasing in elevation back to levels found during the winter. The only exception was 2006, when two large tropical rain events during the summer kept the water table high and no decreasing trend in water tables was found. This was generally true for all of the monitoring blocks at the site. There were some differences in the hydrology of the different monitoring blocks. The first was the residence time of Block 3 that was much lower than Block 1 or Block 2. This was due to the soils at the monitoring depths of Block 3, which had a much higher overall saturated hydraulic conductivity than the other blocks. These residence times should be treated as approximations because of the relatively low number of saturated hydraulic conductivity methods compared to the changes in soils that occurred in the blocks. Block 2 also had a much lower mean gradient than the other monitoring blocks. This was primarily due to the extremely low gradients that were measured in Block 2 during dry periods of the year. About 20% of Block 2 gradients evaluated were negative, meaning that groundwater was likely flowing from the stream toward the pasture, while negative gradients made up less than 1% of measurements in the other monitoring blocks. The last difference that may have been most important was the water table depth below the ground surface. The Block 1 water table was generally closer to the ground surface than either Block 2 or Block

3, especially at the stream edge. The higher water table in Block 1 was also reflected by the wetland vegetation that was present there.

Water Table Proximity to Ground Surface

High water tables and saturated soils are often associated with denitrification because they typically create anaerobic and reduced soil conditions. Wetlands, for example, are identified as prime ecosystems for denitrification. Analyzing the water table depth below the ground surface put the relative wetness of different areas of the buffer into perspective. None of the buffers met the hydrologic requirements for a wetland (USACE, 1987) although the mid-buffer area of Block 1 was likely close as wetland vegetation was present at this location and the wetness of this area was frequently observed in field notes. As shown in Table 15 the differences in the water table proximity to the surface was one of the more notable differences between the monitoring blocks

Table 16 shows the percent of each year that the water table was measured at or above both 30 cm (1 ft) and 60 cm (2 ft) below the ground surface at the pasture edge. A water table within 60 cm of the ground surface indicated that the water table was within the root zone. The root zone is significant because roots are thought to be a source of carbon to drive denitrification. Block 1 and Block 2 were rarely within 60 cm of the ground surface. Block 3 was within 60 cm more frequently likely because of the topography of the blocks. Block 1 and Block 2 both had sharp declines in elevation (about 1.0 m) between the pasture edge and mid-buffer (the interface of zone 3 and zone 2), indicative of the floodplain

associated with the stream. This meant that the ground around the pasture edge water table logger was much higher in relation to the rest of the buffer in Block 1 and Block 2. This decrease in elevation between the upland and floodplain was absent in Block 3. Overall the table shows that the water table was infrequently within 60 cm of the ground surface at the pasture edge throughout the monitoring period.

Table 16. Percent of each year water table was at or above the specified depth for each block at the pasture edge.

Year	Block 1		Block 2		Block 3	
	30 cm	60 cm	30 cm	60 cm	30 cm	60 cm
	<i>(% of year)</i>					
2005	0%	0%	0%	1%	0%	0%
2006	0%	0%	1%	5%	1%	9%
2007	0%	0%	0%	0%	0%	1%
2008	0%	0%	0%	2%	2%	8%
2009	0%	0%	0%	3%	7%	15%

Table 17 shows the percent of each year that the water table was measured at or above both 30 cm (1 ft) and 60 cm (2 ft) below the ground surface at the stream edge of the each buffer. Block 1 clearly had the highest water table at the stream edge when compared to the other blocks. Block 1 had the largest decrease in ground surface elevation across the buffer, that made the water table closer to the ground surface near the stream edge. It was also the monitoring block with the lowest elevation at the monitoring site indicating that more of the upland groundwater may have been draining through it than the other monitoring blocks. Overall, Block 1 appeared to be positioned in the most ideal location to receive and remove the most NO₃-N from groundwater.

Table 17. Percent of each year water table was at or above the specified depth for each block at the stream edge.

Year	Block 1		Block 2		Block 3	
	30 cm	60 cm	30 cm	60 cm	30 cm	60 cm
	<i>(% of year)</i>					
2005	9%	40%	0%	13%	0%	0%
2006	7%	47%	1%	20%	0%	1%
2007	5%	31%	0%	10%	0%	0%
2008	2%	21%	0%	6%	0%	0%
2009	4%	26%	0%	11%	0%	1%

Groundwater Quality – Nitrate (NO₃-N)

Nitrate-nitrogen concentrations were sampled and assessed in the groundwater to determine if concentrations and loads decreased as the groundwater moved from the pasture edge to the stream edge. Figure 79 shows the overall NO₃-N concentrations in each monitoring block. Nitrate-nitrogen concentration values represent samples collected at each well position at both the shallow and deep depths, and concentrations decreased between the pasture edge groundwater and stream edge groundwater in every monitoring block in the study.

The mean Block 1 pasture edge NO₃-N concentration was 12.9 mg/L, the highest of the three monitoring blocks. The Block 2 and Block 3 mean pasture edge concentrations were 7.2 mg/L and 5.2 mg/L respectively. Block 1 pasture edge concentrations were significantly higher than Block 2 or Block 3 pasture edge concentrations. Block 2 and Block 3 pasture edge concentrations were not statistically different ($p= 0.8974$).

The higher mean concentration at the Block 1 pasture edge may have been due to the position of Block 1 in the landscape. It was the lowest elevation block at the site and a large portion of the upland was drained through this portion of the buffer. Another explanation could be that application of the poultry litter was variable in the pasture and may have been higher in the contributing area of Block 1. Cow movement in the pasture seemed to be uniform, but if grazing was more intense in the Block 1 contributing area then this could have also increased the NO₃-N load.

The mean mid-buffer NO₃-N concentration was also highest in Block 1 with a concentration of 6.3 mg/L. Block 2 and Block 3 mean mid-buffer concentrations were much lower at 1.6 mg/L and 2.1 mg/L respectively. All mid-buffer NO₃-N concentrations were significantly different.

Nitrate-nitrogen concentrations at the stream edge were similar in all of the monitoring blocks. Block 1 and Block 3 had mean concentrations at the stream edge of 1.1 mg/L and 1.3 mg/L respectively. Block 2 had a mean concentration of 1.7 mg/L, a slight increase in concentration from the Block 2 mid-buffer NO₃-N mean concentration. The Block 1 stream edge concentrations, that were on average the lowest of all blocks, were found to be statistically different from both Block 2 and Block 3 stream edge concentrations. Block 2 and Block 3 stream edge concentrations were not found to statistically different ($p=0.0728$).

Block 1 also had the largest percent reduction in NO₃-N concentration between the pasture edge groundwater and the stream edge groundwater at 92% while Block 2 and Block 3 reductions had very similar reductions of 76% and 77% respectively.

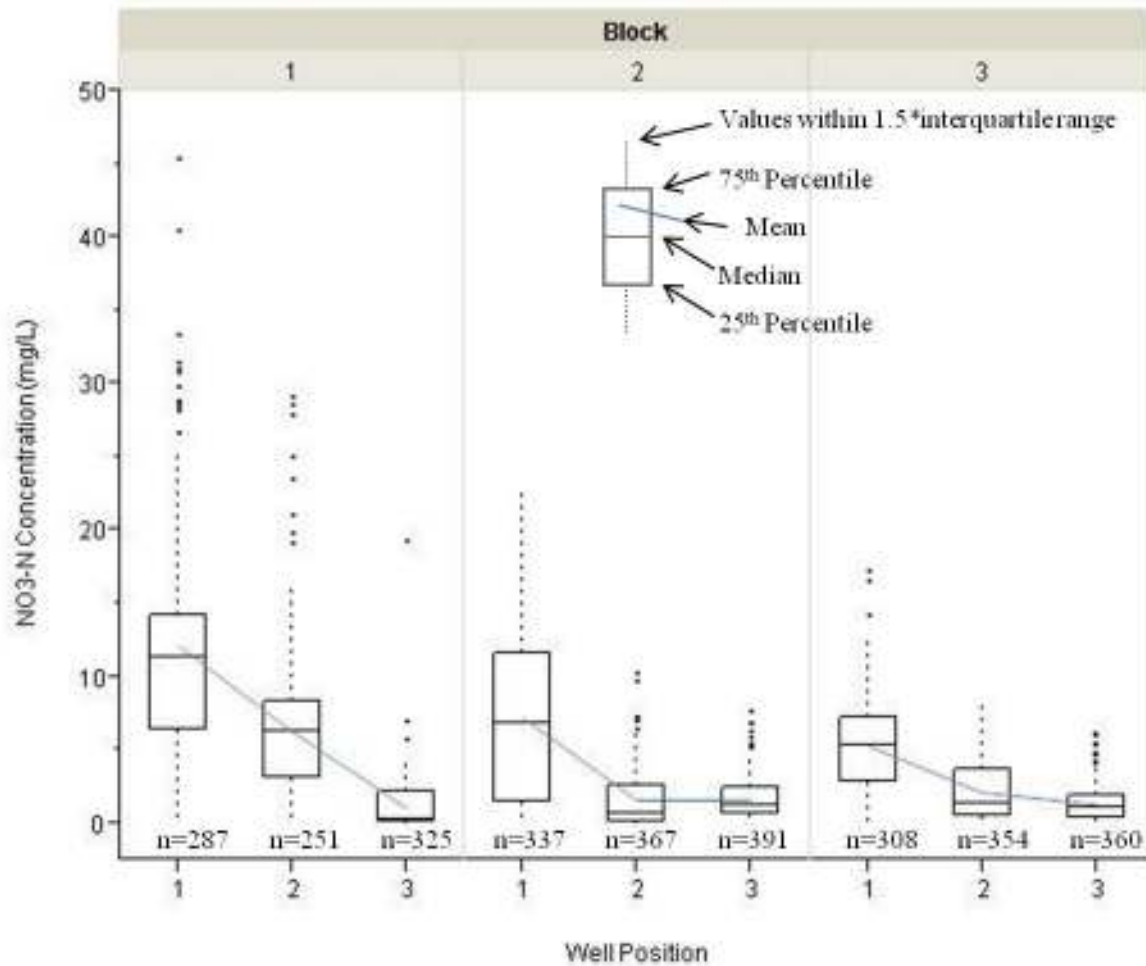


Figure 79. NO₃-N Concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3) for each monitoring block at the buffer site (2005-2009). Lines represent the trend between means at each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: Block 1 PE - 114.8 mg/L, 112.1 mg/L, and 51.7 mg/L.

Redox

Redox potentials were measured to determine if the anaerobic conditions that support the denitrification process were occurring in the buffer and could support that observed reductions in NO₃-N concentrations were due to denitrification. Kralova et al (1992) and Bailey and Beauchamp (1973) found that denitrification was a major process at redox potentials below 200 mV. Bailey and Beauchamp (1973) also found that denitrification could occur at higher potentials, likely up to 400 mV, but that oxygen was simultaneously being utilized at potentials greater than 200 mV. Table 18 shows the percent of redox measurements recorded each year that were below both the +200 mV threshold and the +350 mV threshold. The table shows that a majority of the measurements taken in each block were below the +350 mV threshold in every monitoring year. A majority of the measurements were also below the +200 mV threshold with only a few exceptions, Block 1 in 2008 and 2009 and Block 3 in 2008. This indicated that the potential for denitrification was nearly the same in all of the monitoring blocks and that the potential was fairly high for denitrification to occur throughout a most of each year.

Table 18. Percent of mean redox potential measurements from each block that were below +200 mV or +350 mV.

Year	Block 1		Block 2		Block 3	
	< +200 mV	< +350 mV	< +200 mV	< +350 mV	< +200 mV	< +350 mV
2006 (n=36)	67%	83%	56%	86%	67%	86%
2007 (n=54)	70%	93%	59%	83%	74%	93%
2008 (n=42)	43%	95%	57%	76%	43%	86%
2009 (n=72)	24%	85%	53%	74%	58%	90%

Groundwater Quality – Dissolved Organic Carbon (DOC)

Available carbon in riparian buffers is a major component for denitrification to occur. Figure 80 is a box plot of DOC concentrations from each block at different well positions. Concentrations were similar in all of the monitoring blocks and fairly evenly distributed between the different well positions. This may suggest that the buffer was not accumulating carbon because incoming DOC concentrations (pasture edge) were nearly the same as DOC concentrations leaving the buffer (stream edge). As the buffer matures, the DOC concentration within the buffer may increase compared to the pasture. Mean concentrations ranged between 4.1 mg/L and 6.8 mg/L while medians ranged between 1.6 mg/L and 3.1 mg/L. All wells showed high DOC concentrations on some sampling dates throughout the monitoring period, with many spikes above 15 mg/L. However no strong seasonal trend was detected as indicated in previous chapters.

Mean DOC concentrations in all blocks were on the lower side of the range that promotes denitrification. Obenhuber and Lowrance (1991) found that a small amount of denitrification could occur with DOC concentrations of about 4 mg/L in laboratory microcosms and that the rate drastically increased when DOC concentration were increased to 10 mg/L. Similarly, Starr and Gillham (1993) found that significant denitrification occurred in a sandy aquifer with DOC concentrations from about 5 mg/L to 10 mg/L while almost no denitrification could be identified in a sandy aquifer with 2 mg/L to 3 mg/L concentrations of DOC. While a majority of the DOC sample concentrations were on the lower end of the range for denitrification, sample concentrations at all well positions were frequently measured much higher than threshold concentrations, in some cases above 15 mg/L. This suggests that DOC concentrations in the buffer were sufficient for some denitrification to occur but denitrification may have been carbon limited. During certain periods of high DOC, denitrification was likely a major process in the buffer assuming the other criteria for denitrification were met.

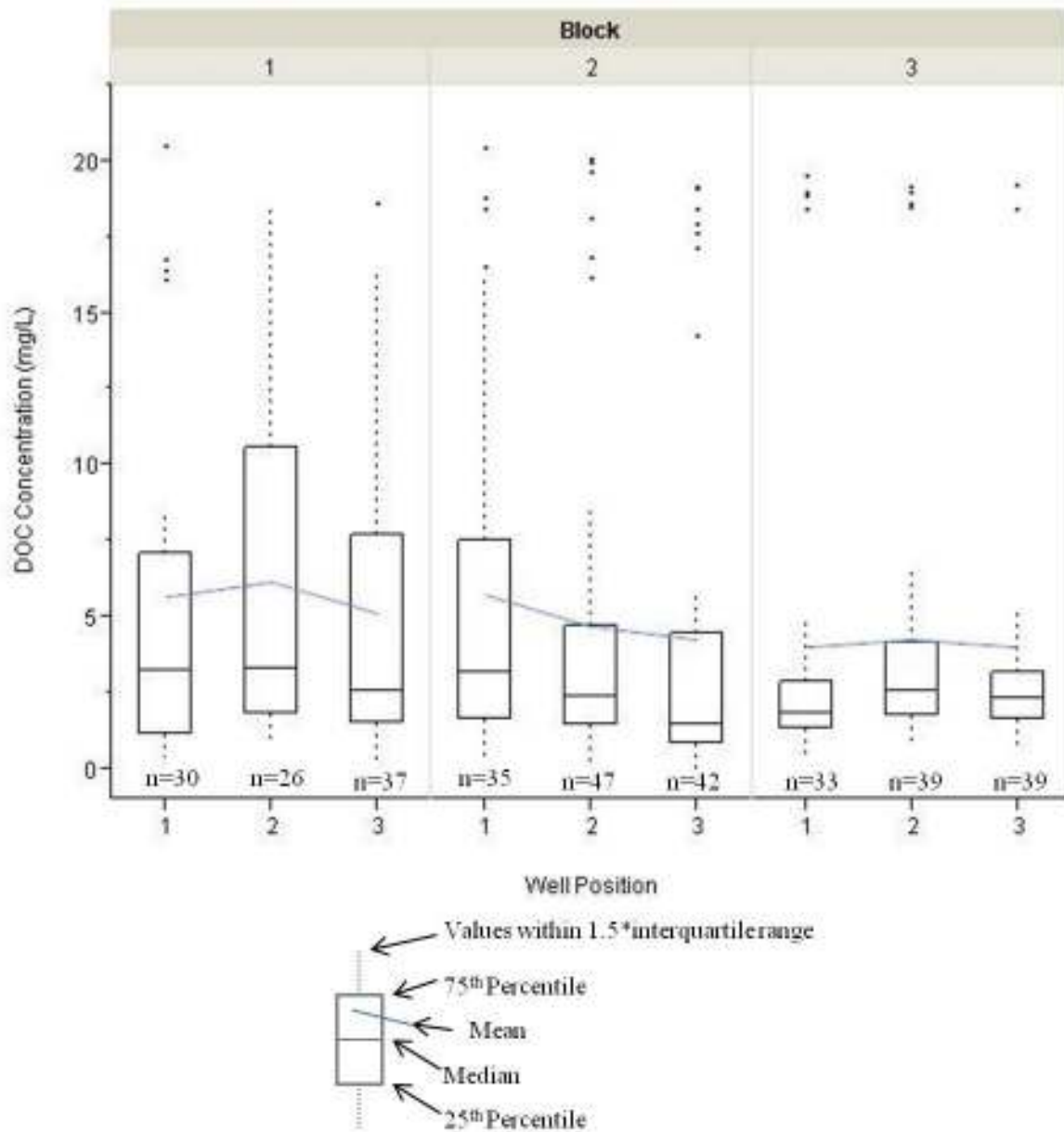


Figure 80. Dissolved organic carbon (DOC) concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3) for each monitoring block at the buffer site. Blue lines represent the trend between means at each well position.

Effect of Dilution – NO₃-N/Cl⁻ Ratios

Chloride concentrations were used to normalize NO₃-N concentrations to determine if NO₃⁻ was actually being removed from the buffer, via vegetation uptake or denitrification, or if concentrations were being lowered by NO₃⁻ poor groundwater mixing with the surficial aquifer. Typically, NO₃-N concentrations are divided by the Cl⁻ concentration to create a ratio that can be analyzed. NO₃-N /Cl⁻ ratios that decrease from the pasture edge to the stream edge are usually associated with NO₃-N removal in the buffer. Ratios that do not change from the pasture edge to the stream edge are indicative of no NO₃-N removal, only dilution by a NO₃-N and Cl⁻ poor groundwater source or an inert buffer making no changes. Ratios that increase across the buffer would be considered inconclusive because it would indicate that either NO₃-N concentrations were increasing, Cl⁻ concentrations were decreasing, or both of these changes were occurring simultaneously. This method works best when Cl⁻ concentrations remain at nearly the same concentration across the buffer. Figure 81 shows NO₃-N/Cl⁻ ratios for each block and shows that ratios decreased in all monitoring blocks at the site, which if taken alone would conclude that biological NO₃-N removal was occurring in the buffer.

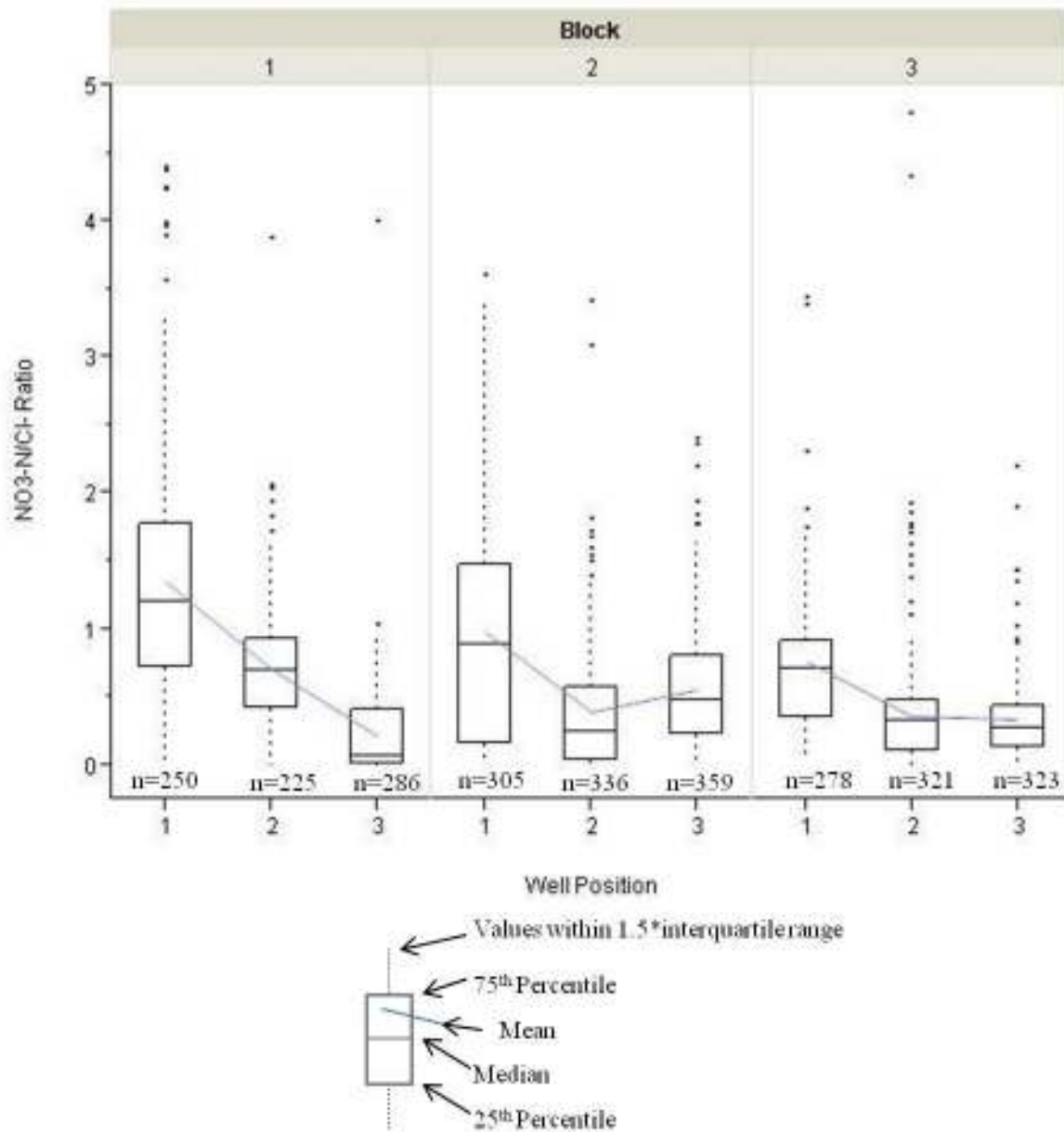


Figure 81. NO₃-N/Cl ratios for each block at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3) for each monitoring block at the buffer site. Lines represent the trend between means at each well position.

However, Cl^- concentrations decreased between the pasture edge groundwater and stream edge groundwater in all of the monitoring blocks indicating some dilution. The rate of decrease in $\text{NO}_3\text{-N}$ concentrations between the pasture edge groundwater and stream edge groundwater was slightly higher than the decrease in Cl^- concentrations indicating some biological removal.

Figure 82 shows the Cl^- concentrations at each well position in each of the blocks. As shown in the figure, Cl^- concentrations had a large range at each well position.

Overall, values at the pasture edge were similar in each of the monitoring blocks. The highest mean pasture edge concentration was Block 1 with a mean Cl^- concentration of 13.7 mg/L. Block 2 and Block 3 were similar with concentrations of 11.9 and 10.7 mg/L respectively. Statistically the pasture edge Block 1 concentrations were not different from the pasture edge Block 2 concentrations ($p= 0.1171$) but were different from the pasture edge Block 3 concentrations. Block 2 and Block 3 were not different at the pasture edge ($p= 0.4481$).

Chloride Concentrations at the stream edge were also similar between the different monitoring blocks. Block 1 mean stream edge concentration was 4.8 mg/L, Block 2 was 3.9 mg/L and the mean Block 3 stream edge concentration was 5.7 mg/L. Block 1 stream edge concentrations were found to be significantly different from Block 2 stream edge concentrations but not different from Block 3 stream edge concentrations ($p= 0.5503$).

Block 2 stream edge concentrations were also found to be statistically different from Block 3 stream edge concentrations.

All blocks showed a statistically significant decrease in Cl^- concentrations between the pasture edge and the stream edge. This was most likely due to surficial groundwater mixing with deeper groundwater and rainfall which diluted Cl^- concentrations as the surficial groundwater moved from the pasture edge to the stream edge. Block 1 had an overall percent reduction in Cl^- concentrations between the pasture edge and stream edge of 63%, Block 2 reduction was 65%, and Block 3 reduction was 48%. This dilution of the surficial groundwater with a different Cl^- poor groundwater source was also thought to be a major contributor to the reduction of $\text{NO}_3\text{-N}$ concentrations found in the buffer.

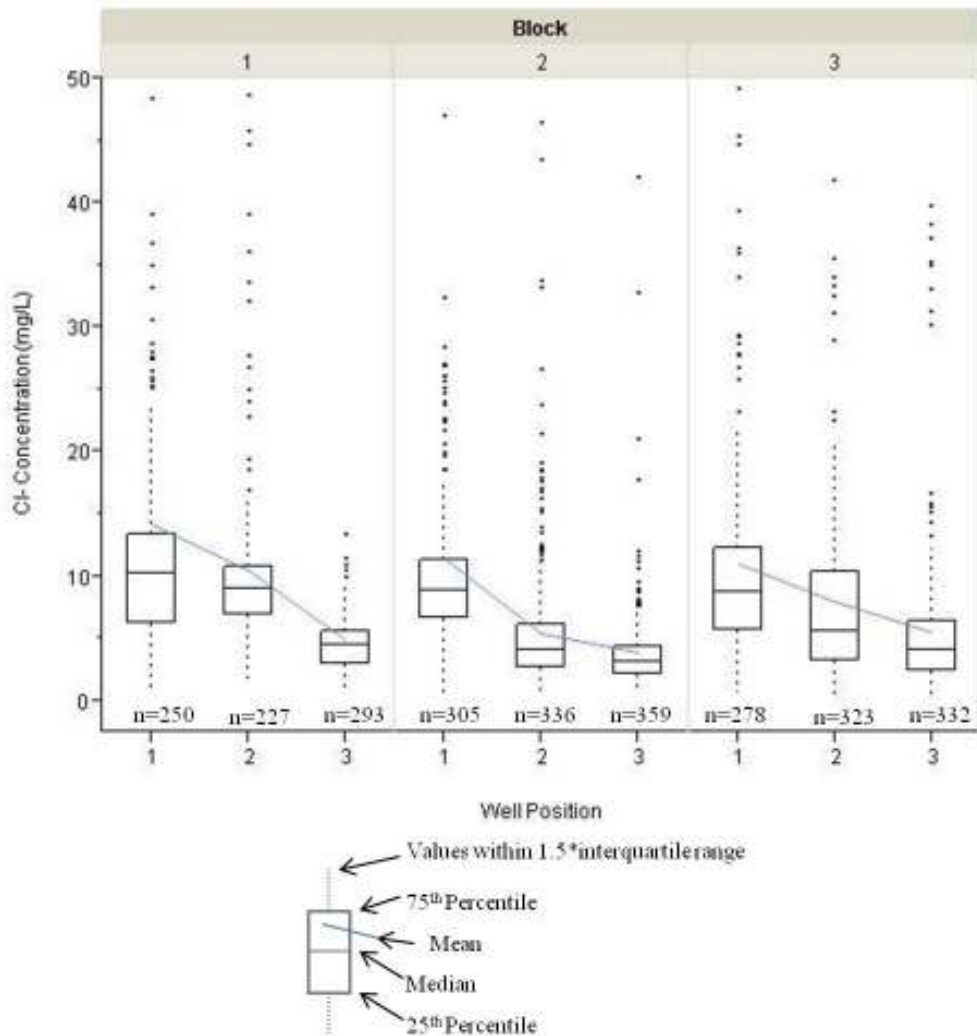


Figure 82. Cl⁻ concentrations at the pasture edge (well position 1), mid-buffer (well position 2), and stream edge (well position 3) for each monitoring block at the buffer site. Lines represent trend between means at each well position. Note: range of y-axis was minimized by omitting the following values from the figure but not from the analysis: Block 1 PE - 460.0 mg/L, 126.0 mg/L, 108.0 mg/L, 86.7 mg/L, 76.5 mg/L, 52.5 mg/L, Block 1 MB - 73.6 mg/L, 55.4 mg/L, Block 1 SE - 98.0 mg/L, 61.6 mg/L, Block 2 PE - 400.0 mg/L, 154.0 mg/L, Block 2 SE - 72.5 mg/L, 55.8 mg/L, Block 3 PE - 79.2 mg/L, 65.1 mg/L, 52.1 mg/L, 54.7 mg/L, and 50.1 mg/L, Block 3 MB - 91.2 mg/L, 55.5 mg/L, and Block 3 SE - 83.1 mg/L.

To better understand the role of dilution and to estimate the amount of $\text{NO}_3\text{-N}$ reduction that could be credited to biological removal required further analysis. The mean $\text{NO}_3\text{-N}$ and Cl^- concentrations for pasture edge and stream edge groundwater samples were calculated for each sampling date. Next the percent reduction in concentration between the pasture edge and stream edge mean was calculated for both $\text{NO}_3\text{-N}$ and Cl^- concentrations for each sampling date in the monitoring period. The analysis again showed that both $\text{NO}_3\text{-N}$ and Cl^- concentrations decreased on a majority of the sampling dates, but that $\text{NO}_3\text{-N}$ concentrations decreased at a faster rate than Cl^- concentrations between the pasture edge and stream edge. Percent reductions in $\text{NO}_3\text{-N}$ concentration that exceeded the percent reduction in Cl^- concentration was thought to be the best estimate of $\text{NO}_3\text{-N}$ reductions that could be attributed to biological removal, most likely denitrification. It should be noted that this would be the maximum amount of biological removal that could be expected from the buffer. Groundwater that was sampled at very deep depths at the stream edge, and was thought to be the diluting source of groundwater, usually had concentrations of Cl^- that were slightly higher than $\text{NO}_3\text{-N}$ concentrations. Mean $\text{NO}_3\text{-N}$ concentrations were 2.5 mg/L, 0.8 mg/L, and 2.6 mg/L in the stream edge deep groundwater for Block 1, Block 2, and Block 3 respectively while mean Cl^- concentrations were 5.4 mg/L, 3.0 mg/L, and 7.3 mg/L for Block 1, Block 2, and Block 3 respectively. This could have caused the $\text{NO}_3\text{-N}$ concentrations to decrease at a faster rate. However, for this analysis, dilution was assumed to have the same effect on both $\text{NO}_3\text{-N}$ and Cl^- concentrations. This was similar to a method used by Schoonover and Williard (2003). The percent reduction between the pasture edge and stream edge $\text{NO}_3\text{-N}$

concentrations was subtracted from the percent reduction between the pasture edge and stream edge Cl^- concentrations to estimate the NO_3-N reduction that was due to biological removal for each sampling date as shown in equation 10:

$$\Delta NO_3 - N\% - \Delta Cl^- \% = \Delta NO_3 - N\% \text{ due to biological removal} \quad [10]$$

Block 1 had the highest mean estimated biological removal of 40%, while Block 2 and Block 3 had lower removals of 17% and 32% respectively.

These removals were less than what was been reported by previous researchers who calculated removals of between 75-99% (Altman and Parizek, 1995; Schoonover and Williard, 2003; Vellidis et al., 2003). However, the values are similar to those found by Clausen et al (2000) who reported a 35% N removal in the buffer groundwater, as well as, Dukes et al. (2002) and Snyder et al. (1998) who reported ranges of 28-84% and 16-70% respectively due to variability among buffers within each of their own studies. All of these studies accounted for dilution using some form of tracer except Snyder et al. (1998).

Cations in the groundwater, in this case Na^+ and Ca^{2+} , were assessed by elevation to determine if the groundwater was separated between the surficial aquifer, where the shallow and deep wells were located, and the aquifer that was below the saprolitic layer that occurred throughout the site. No meaningful difference between the two aquifers was found within the buffer in any of the monitoring blocks. This indicated that the aquifers were able to interact and was further evidence that groundwater mixing, and subsequent dilution of concentrations, was likely occurring at the site.

Discussion and Conclusion

Significant reductions in $\text{NO}_3\text{-N}$ concentrations between the pasture edge and stream edge groundwater occurred in all 3 monitoring blocks at the site. Block 1 concentrations had the highest mean percent reduction in concentrations at 92%. Block 2 and Block 3 had similar mean percent reductions of 76% and 77% respectively.

However, not all of the reductions in $\text{NO}_3\text{-N}$ concentration could be attributed to biological removal. Chloride concentrations also decreased significantly between the pasture edge and stream edge in all of the monitoring blocks. This indicated that a portion of the reduction in $\text{NO}_3\text{-N}$ concentrations found in surficial groundwater was due to groundwater mixing with a $\text{NO}_3\text{-N}$ and Cl^- poor groundwater source. Mean Cl^- percent reductions between pasture edge groundwater and stream edge groundwater of 63%, 65%, and 48% for Block 1, Block 2, and Block 3 respectively showed that dilution was a significant process in the reduction of $\text{NO}_3\text{-N}$ concentrations.

The actual biological removal of $\text{NO}_3\text{-N}$ from the buffer was estimated by subtracting the dilution effect, the reduction in Cl^- concentrations, from the reduction in $\text{NO}_3\text{-N}$ concentrations. These estimates were considered the maximum amount of biological removal, likely denitrification, that could have occurred in the buffer. Mean biological removals of 40%, 17%, and 32% were calculated for Block 1, Block 2, and Block 3 respectively, much lower than the overall reductions in $\text{NO}_3\text{-N}$ concentrations.

Variable Cl^- concentrations reduced the confidence in the biological removal results. The variability could be due to a number of reasons. The first possibility is that dilution of Cl^- concentrations in the groundwater was not occurring at the same rate throughout the monitoring period. This seemed plausible, however, no seasonal trend in Cl^- concentrations could be detected. Another possibility is that the source of Cl^- , in this case poultry litter that was applied to the pasture, was not broadcast evenly across the pasture or was naturally variable in Cl^- content. Records of fertilizer application and calibration of the broadcast machinery unfortunately could not be obtained for the monitoring period. Chloride contributions from cows in the pasture were also likely variable depending on where grazing was the most intense previous to the sampling. The use of Cl^- to assess groundwater mixing is still recommended for use in other similar studies although the use of another conservative tracer as a comparison or another method of detecting biological removal of NO_3^- is recommended for more confident results. It is clear that some method of detecting and quantifying groundwater mixing is necessary for a complete conclusion. Studies seeking to understand the fate and movement of a contaminant in groundwater that do not account for groundwater mixing, and subsequent dilution of concentrations, may overestimate the contribution of other processes to any concentration reductions.

Other measurements from the buffer, meant to confirm if conditions were conducive for denitrification, indicated that there was potential throughout the monitoring period. Overall, mean redox potentials were within the range where denitrification has been shown to occur ($\leq +350$ mV). Many of the potentials were below the +200 mV threshold, where

denitrification is a primary processes and the potential for biological N removal from the buffer is very high. There was very little difference in potentials between the different monitoring blocks which indicated that denitrification could have occurred in any of the monitoring blocks assuming the other conditions were met.

Mean DOC concentrations in all monitoring blocks were probably marginal for high rates of denitrification to occur and DOC concentrations may have been a limiting factor for denitrification in the buffer. However, spikes of DOC to concentrations of 10 mg/L or above, where high rates of denitrification have been measured by other researchers (Obenhuber and Lowrance, 1991), occurred throughout the year. During these periods the potential for denitrification was very high. Dissolved organic carbon concentrations were slightly higher in Block 1 when compared to Block 2 or Block 3. Mean DOC concentrations were 5.7 mg/L, 4.5 mg/L, and 4.1 mg/L for Block 1, Block 2, and Block 3 respectively.

Block 1 slightly outperformed Block 2 and Block 3 in biological removal and the higher overall DOC concentrations may have been a primary factor. The higher DOC concentration in Block 1 was thought to be due to the water table being closer to the ground surface. The ground surface usually has higher available carbon than deeper soil horizons and the Block 1 water table likely leached carbon from the upper soil horizons more frequently than the other monitoring blocks.

While dilution due to groundwater mixing is not the preferred process of $\text{NO}_3\text{-N}$ concentration reduction in riparian buffers, the buffer may have still had an important role in

improving water quality. The $\text{NO}_3\text{-N}$ load entering the stream would have likely been greater if the pasture had extended all the way to the edge of the stream due to increased surface runoff and an increase in the $\text{NO}_3\text{-N}$ laden contributing area. The buffer acted as a barrier to surface runoff and a physical area where almost no additional $\text{NO}_3\text{-N}$ would be added to the groundwater so that $\text{NO}_3\text{-N}$ concentrations, from the pasture, could be diluted or transformed. A control block at the site, consisting of fertilized pasture up to the stream edge with no buffer, would have helped to confirm or dispel this conclusion.

Other future work in this monitoring block could investigate the effect of raising the water table in parts of the buffer and assessing if $\text{NO}_3\text{-N}$ reductions are affected. High water tables are considered an important characteristic of riparian buffers when NO_3^- reduction in groundwater is a major goal. Higher water tables could provide anaerobic conditions for longer periods of each year and could possibly increase DOC concentrations in groundwater by leaching carbon from the upper horizons of the soil. This would likely translate to higher overall denitrification rates and a more effective buffer.

Overall this study seemed to suggest that, if treatment of NO_3^- is a major goal, the best places to site riparian buffers is where water tables frequently come into contact with the upper soil horizons throughout the year. This allows the buffer to recharge its available carbon in the groundwater increasing the potential for denitrification to occur and likely higher removal percentages. As long as NO_3^- treatment remains a major goal, recommendations to CREP include siting future riparian buffers in areas with very poorly-

drained soils or hydric soils where maximum denitrification is likely to occur. Nitrate water quality credits should be reviewed and possibly reduced for riparian buffers, especially those where the water table rarely comes into contact with the upper soil horizons or where dilution is suspected to be a major process. Dilution is not likely to be obvious when choosing riparian buffer sites, so all site investigations should attempt to account for it using some method. Otherwise, as this study shows, the amount of NO₃-N reduction attributed to denitrification or other biological processes can be overestimated.

References

- Altman, S.J. and R.R. Parizek. 1995. Dilution of nonpoint-source nitrate in groundwater. *Journal of Environmental Quality* 24, 707-718.
- Bailey, L.D., and E.G. Beauchamp. 1973. Effects of moisture, added NO_3^- , and macerated roots on NO_3^- transformation and redox potential in surface and subsurface soils. *Canadian Journal of Soil Science* 53(2), 219-230.
- Clausen, J.C., Guillard, K., Sigmund, C.M., Dors, K. Martin. 2000. Water quality changes from riparian buffer restoration in Connecticut. *Journal of Environmental Quality* 29(6), 1751-1761.
- Dukes, M.D.; Evans, R.O.; Gilliam, J.W.; Kunickis, S.H. 2002. Effect of riparian buffer width and vegetation type on shallow groundwater quality in the middle coastal plain of North Carolina. *Transactions of the American Society of Agricultural Engineers* 45(2), 327-336.
- Gold, A.J., P.A. Jacinthe, P.M. Groffman, W.R. Wright, and R.H. Puffer. 1998. Patchiness in groundwater nitrate removal in a riparian forest. *Journal of Environmental Quality* 27, 146-155.
- Kralova, M., P.H. Masscheleyn, C.W. Lindau, W.H. Patrick, Jr. 1992. Production of dinitrogen and nitrous oxide in soil suspensions as affected by redox potential. *Water, Air, and Soil Pollution* 61, 37-45.
- Natural Resource Conservation Service. 2008. Web soil survey: Halifax County, NC. Available at <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>. Accessed on April 15, 2009.
- Obenhuber, D.C. and R. Lowrance. 1991. Reduction of nitrate in aquifer microcosms by carbon additions. *Journal of Environmental Quality* 20(1), 255-258.
- Pinay, G., L. Roques, A. Fabre. 1993. Spatial and temporal patterns of denitrification in a riparian forest. *The Journal of Applied Ecology* 30 (4), 581-591.
- Schoonover, Jon E.; Williard, Karl W.J. 2003. Ground water nitrate reduction in giant cane and forest riparian buffer zones. *Journal of the American Water Resources Association* 39(2), 347-354.

- Snyder, N.J., S. Mostaghimi, D.F. Berry, R.B. Reneau, S. Hong, P.W. McClellan, and E.P. Smith. 1998. Impact of riparian forest buffers on agricultural nonpoint source pollution. *Journal of the American Water Resources Association* 34(2), 385-395.
- Starr, R.C. and R.W. Gillham. 1993. Denitrification and organic carbon availability in two aquifers. *Groundwater* 31(6), 934-947.
- United States Army Corps of Engineers. 1987. Corps of Engineers Wetland Delineation Manual. Accessed at <http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf>.
- Vellidis, G.; Lowrance, R.; Gay, P.; Hubbard, R.K. 2003. Nutrient transport in a restored riparian wetland. *Journal of Environmental Quality* 32, 711-726.
- Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. USDA-FS publication No. NA-PR-07-91. Radnor, Pa.: USDA-FS. Accessed at http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm.
- Zublena, J.P., J.C. Barker, T.A. Carter. 1996. Poultry manure as a Fertilizer source. *North Carolina Cooperative Extension Service*. Pub. No. AG-439-5. Accessed at: http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag439_5.html

APPENDICES

APPENDIX A: Chapter 2 Supplemental (Block 1)

Block 1 Groundwater Hydrology

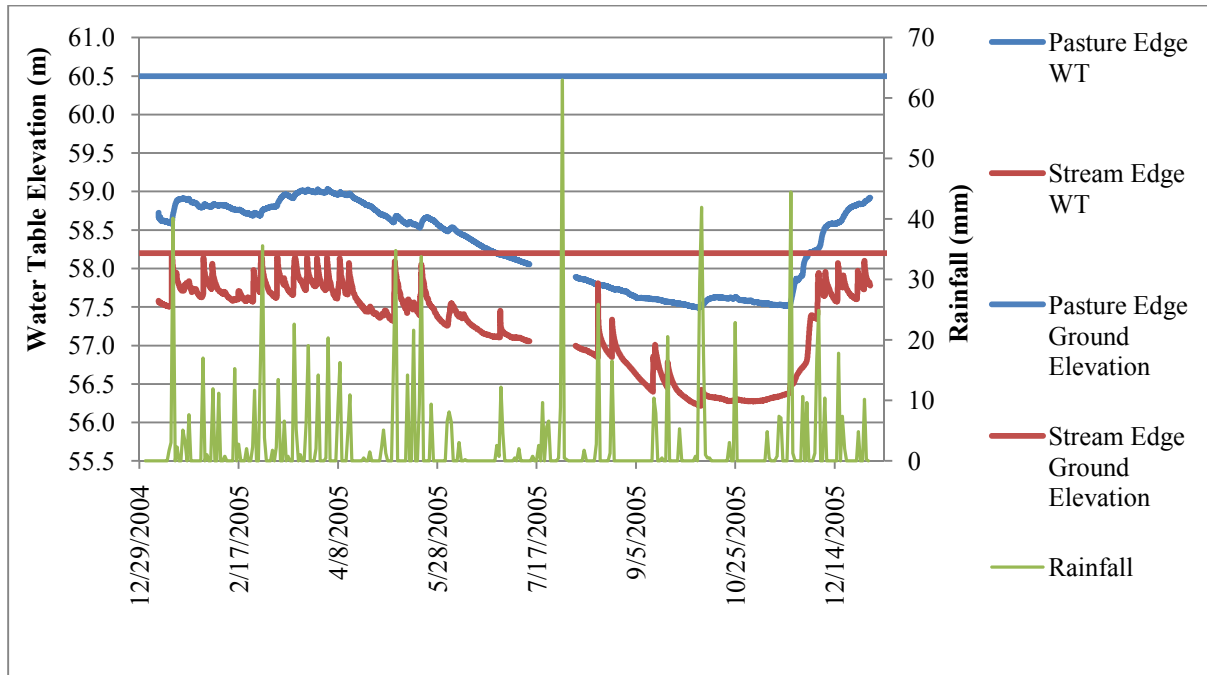


Figure 83. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2005.

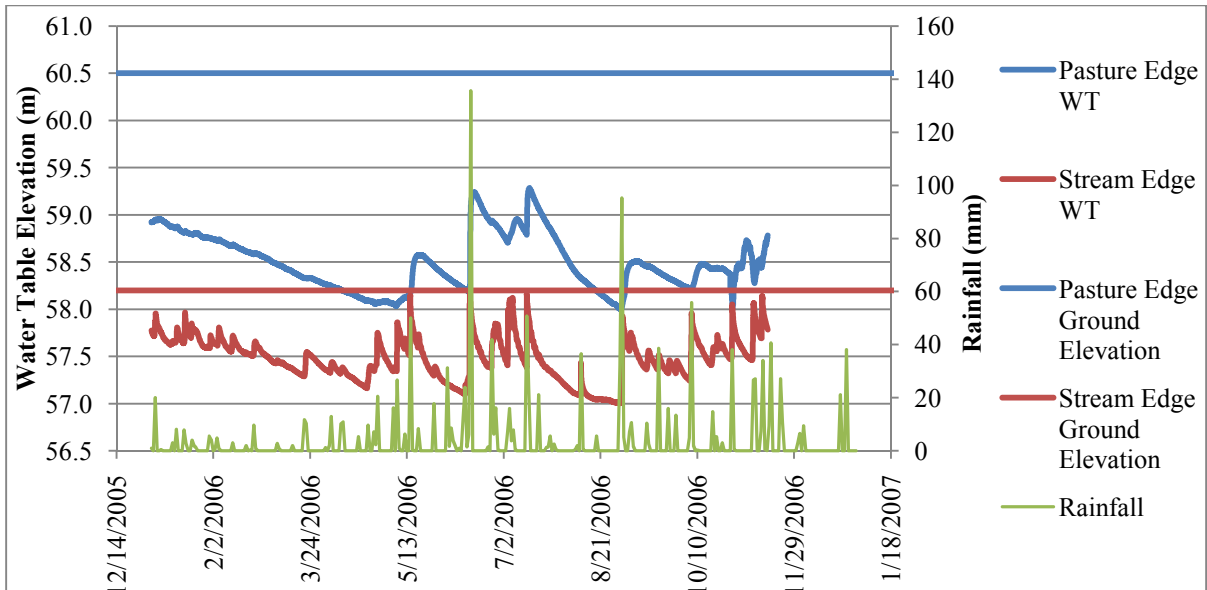


Figure 84. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2006.

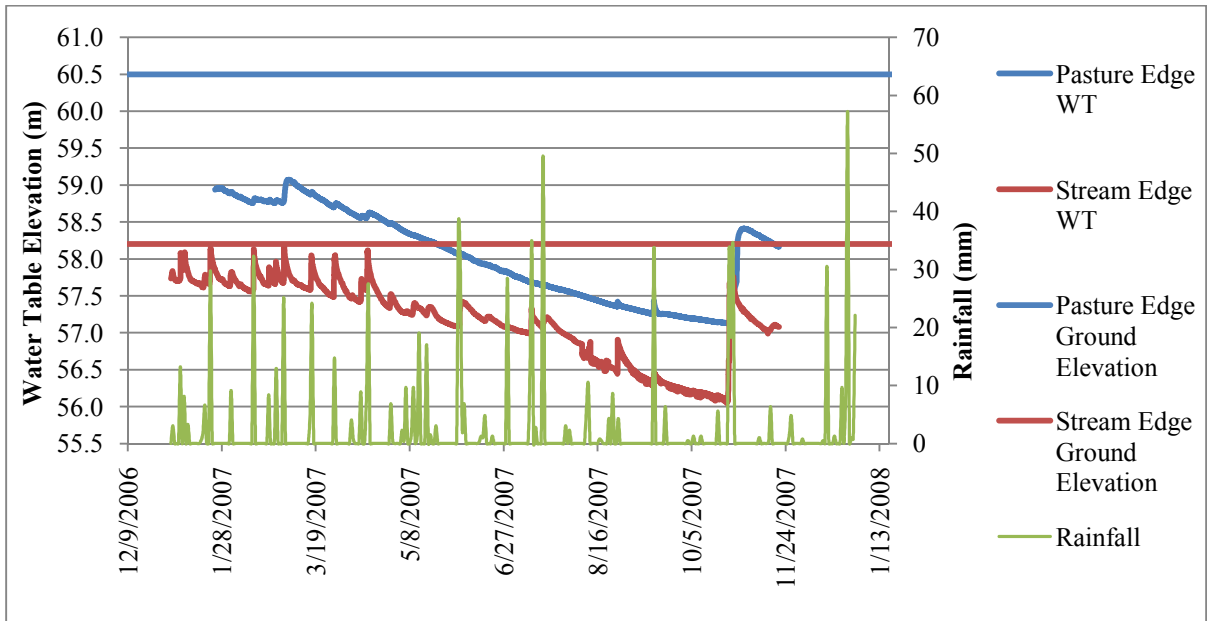


Figure 85. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2007.

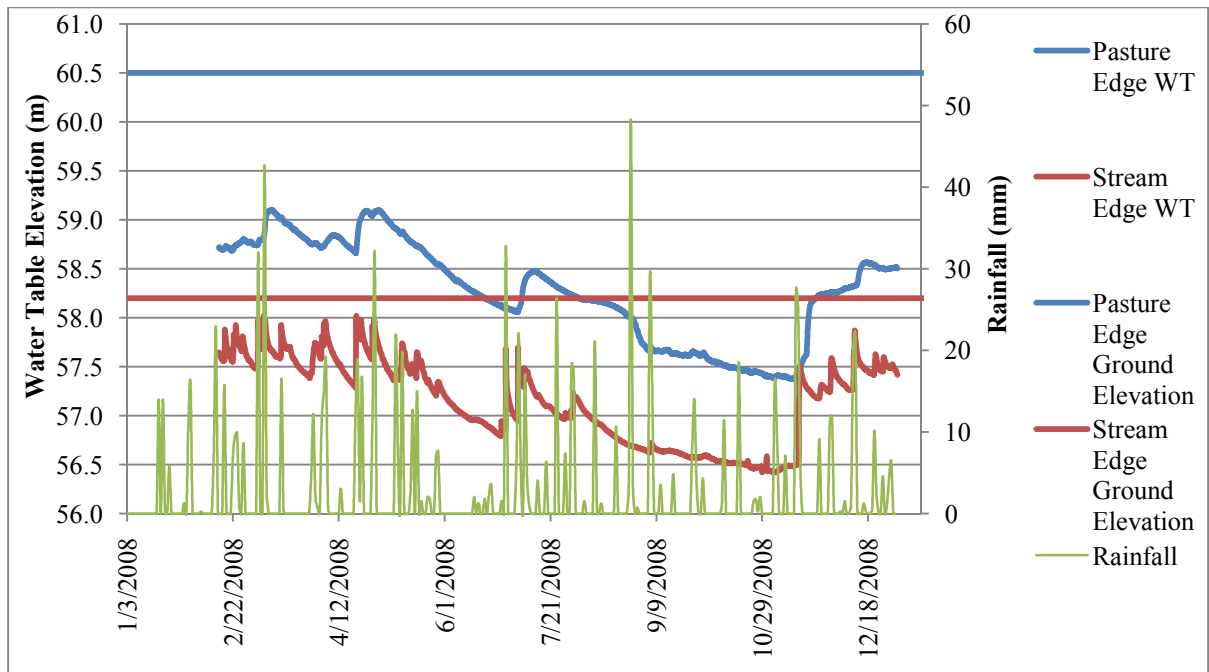


Figure 86. Block 1 water table elevations at the pasture edge and stream edge and rainfall amounts in 2008.

Block 1 Pasture Edge Redox

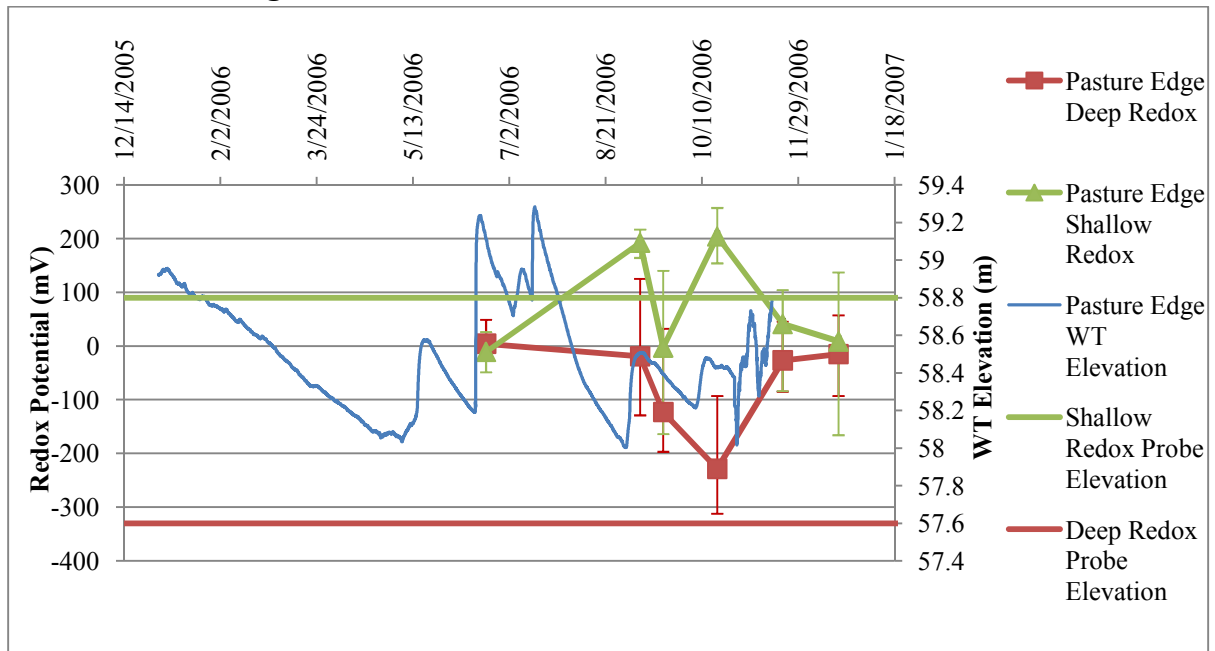


Figure 87. Mean pasture edge redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

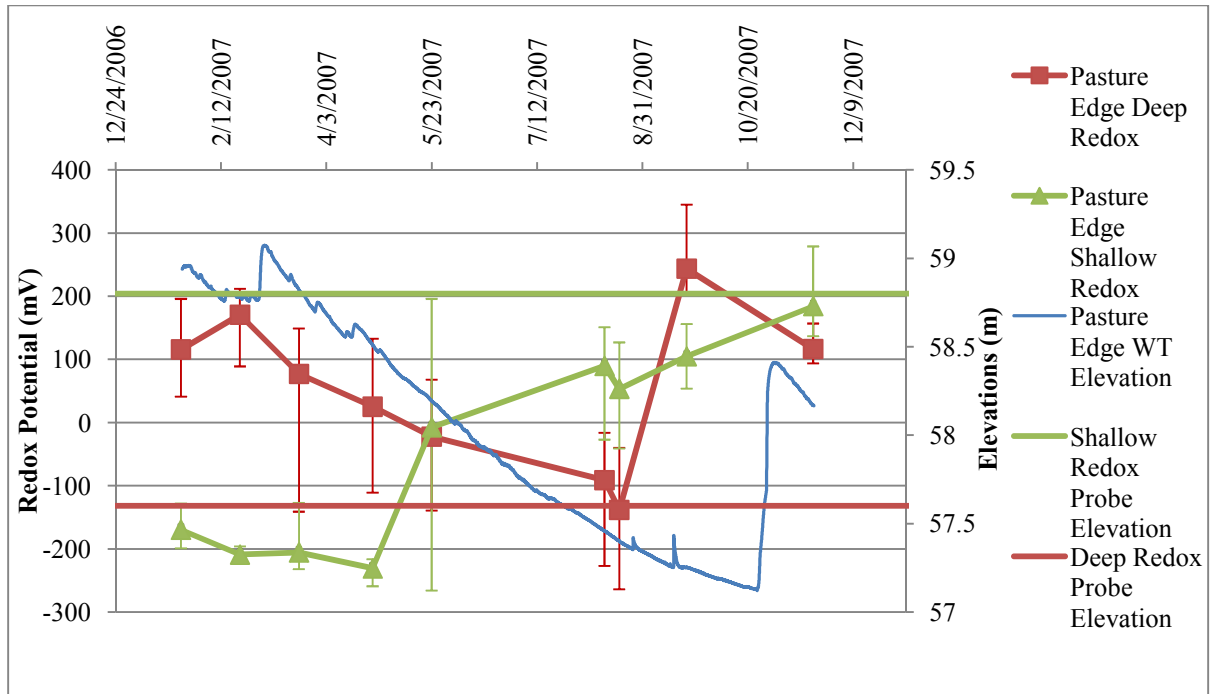


Figure 88. Mean pasture edge redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

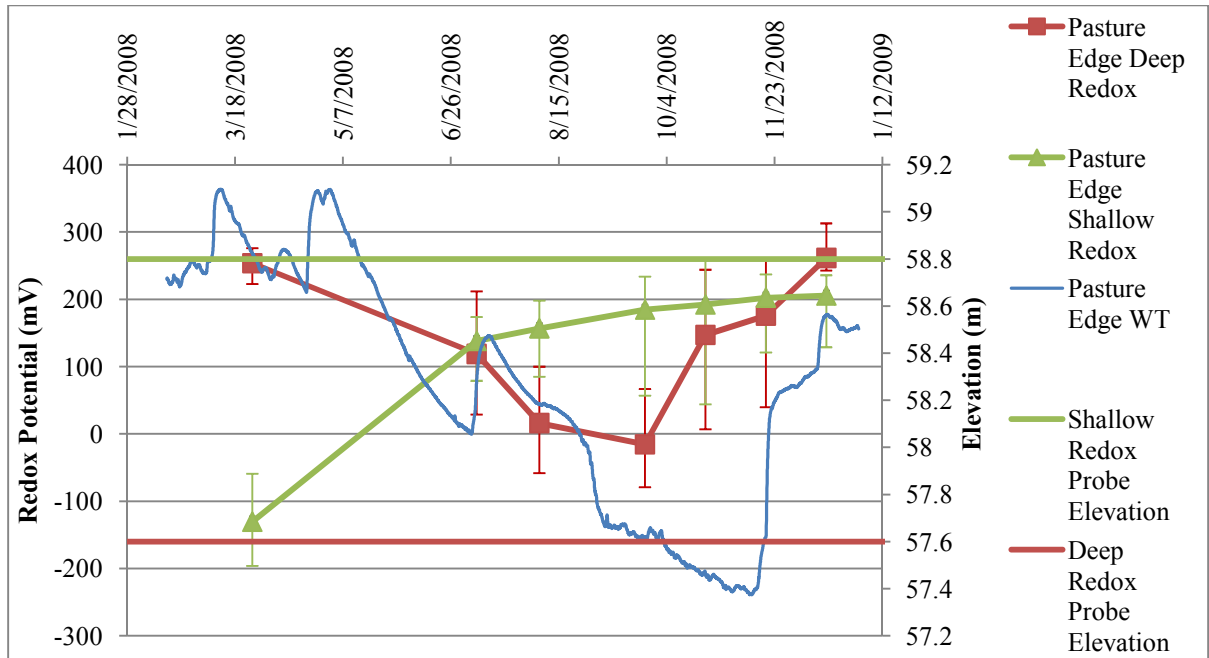


Figure 89. Mean pasture edge redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Block 1 Mid-Buffer Redox

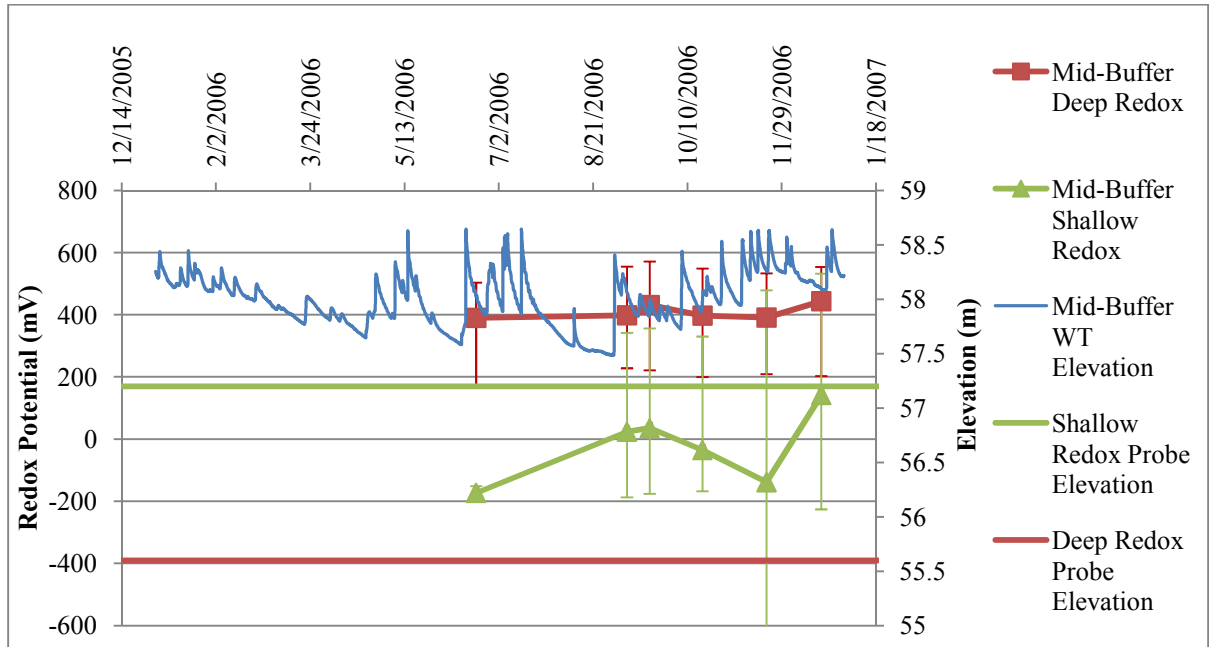


Figure 90. Mean mid-buffer redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

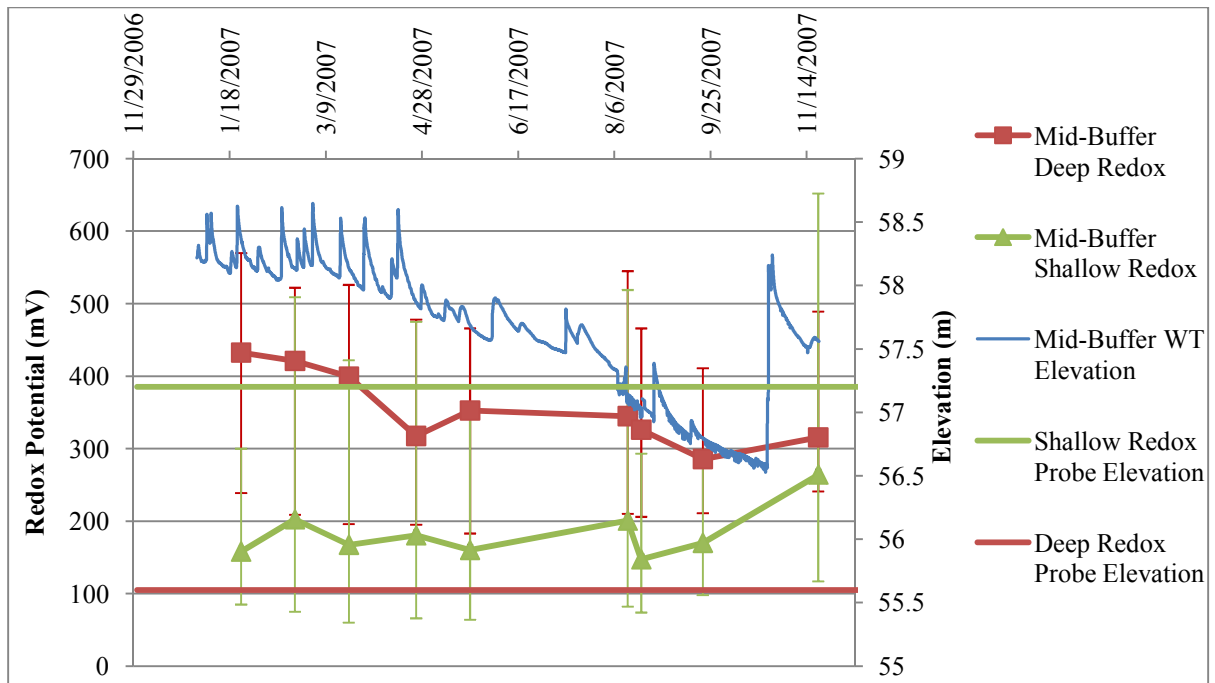


Figure 91. Mean mid-buffer redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

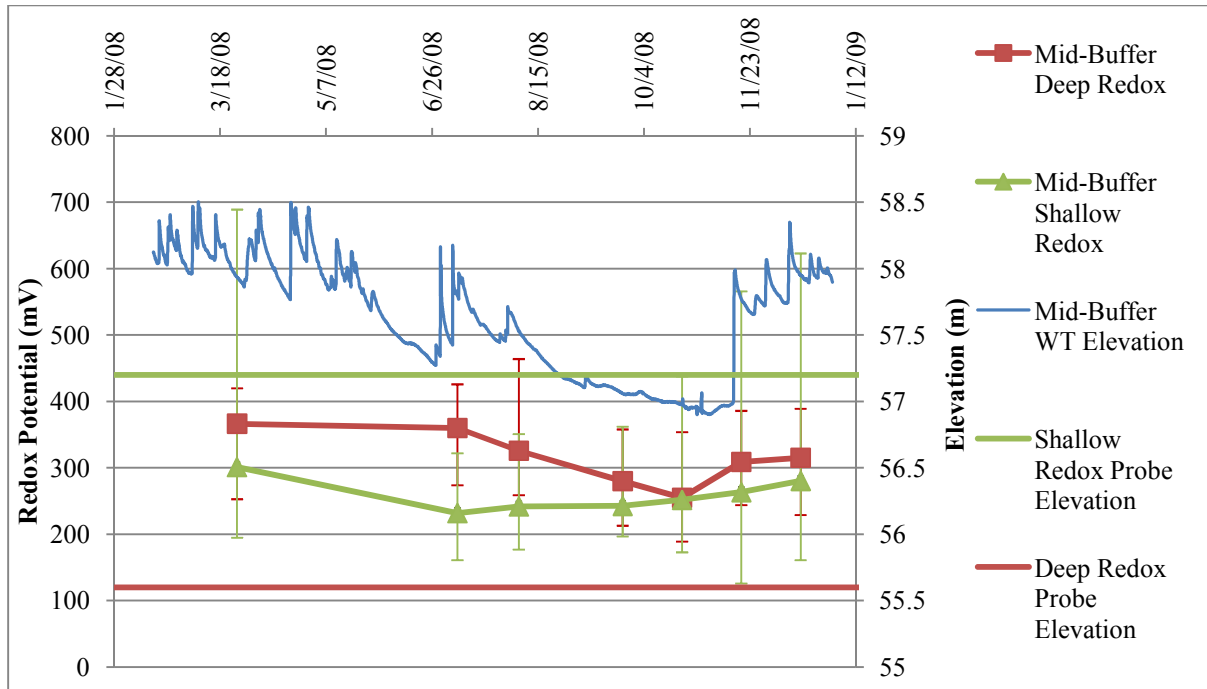


Figure 92. Mean mid-buffer redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Block 1 Stream Edge Redox

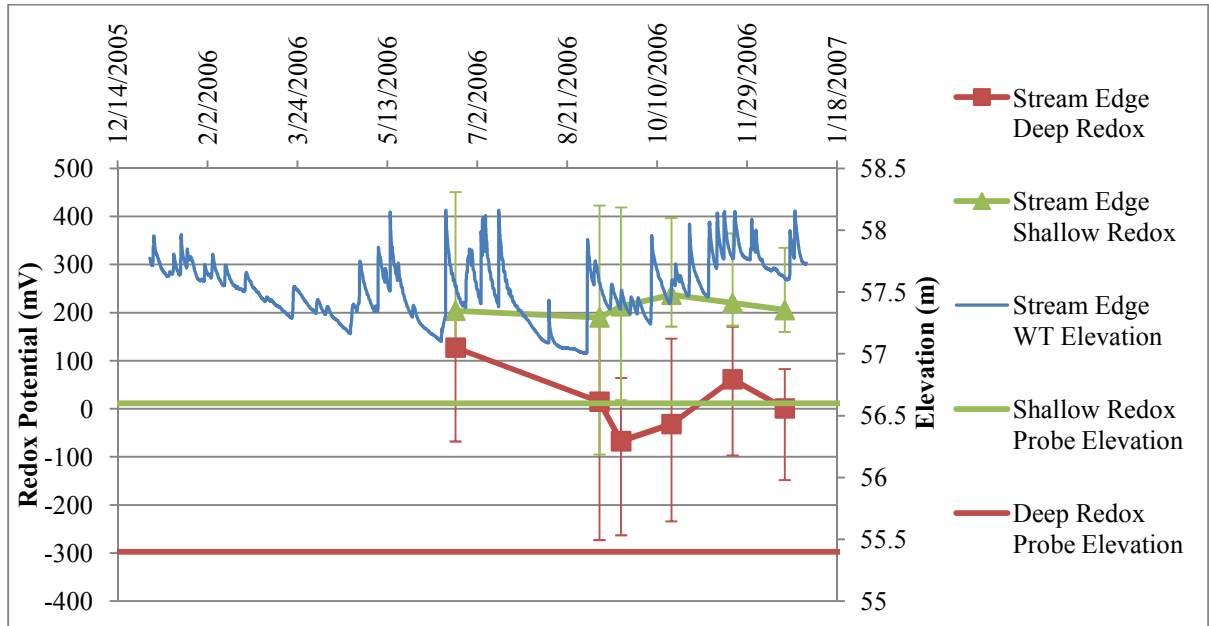


Figure 93. Mean stream edge redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

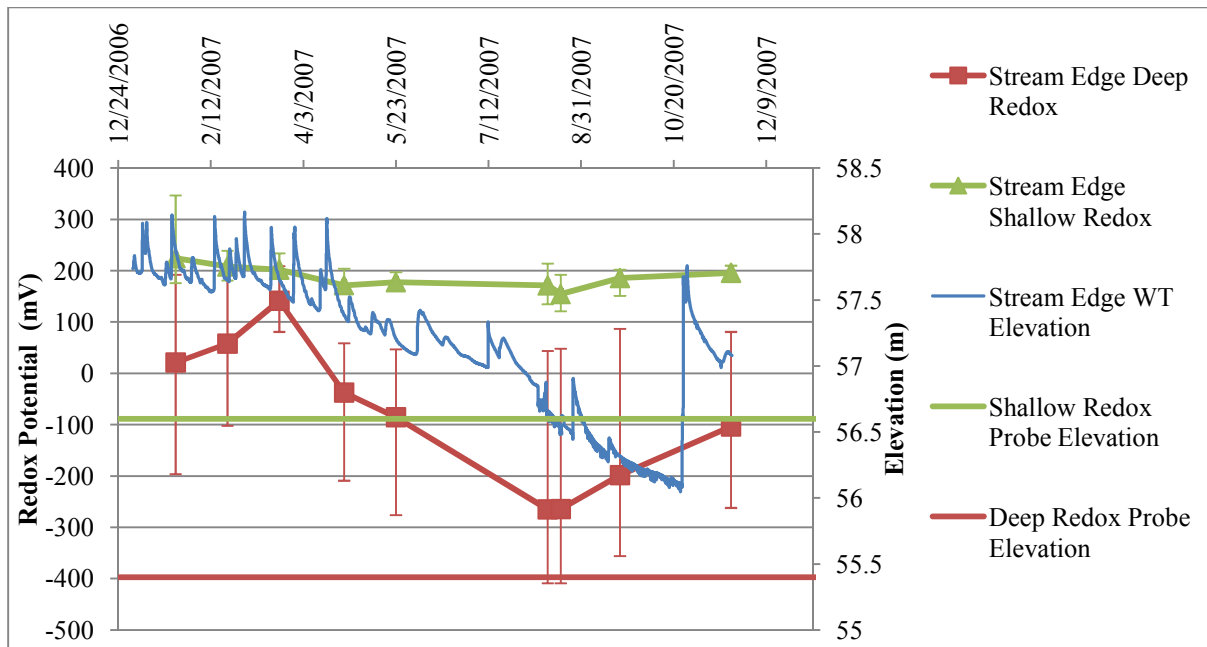


Figure 94. . Mean stream edge redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

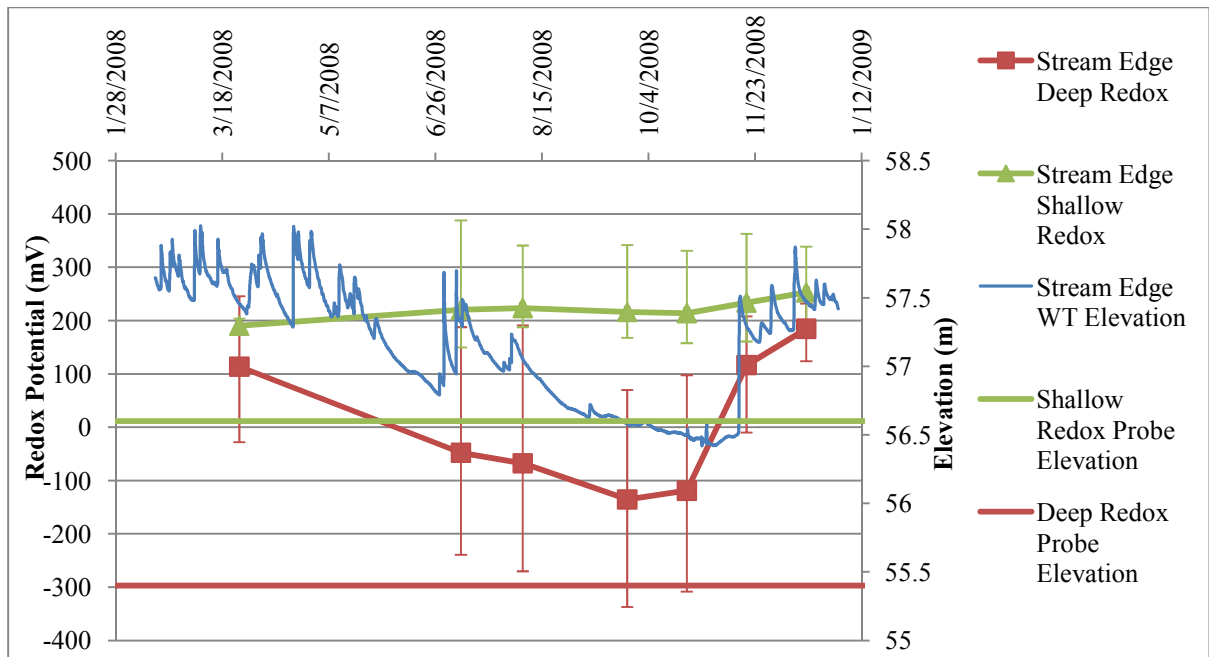


Figure 95. Mean stream edge redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

APPENDIX B: Chapter 3 Supplemental (Block 2)

Block 2 Groundwater Hydrology

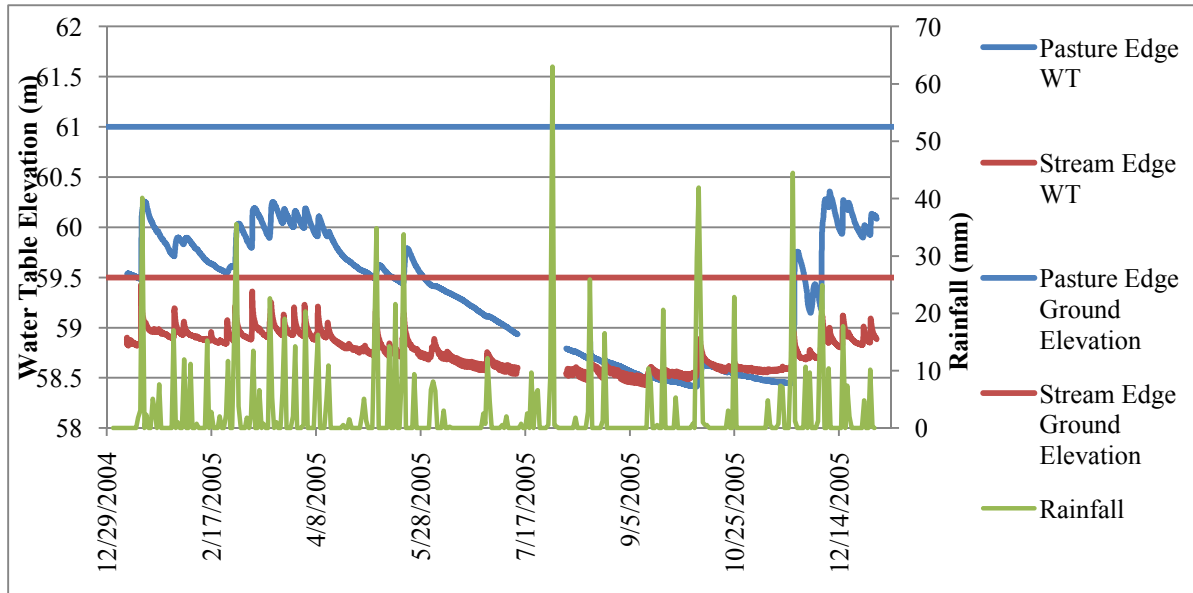


Figure 96. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2005.

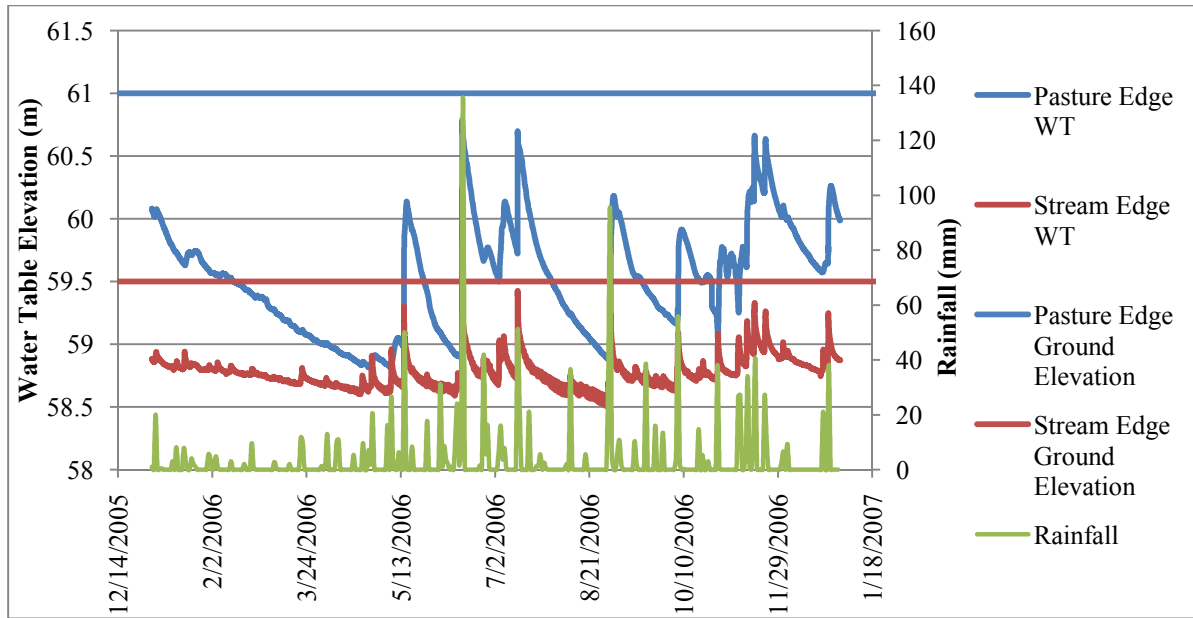


Figure 97. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2006.

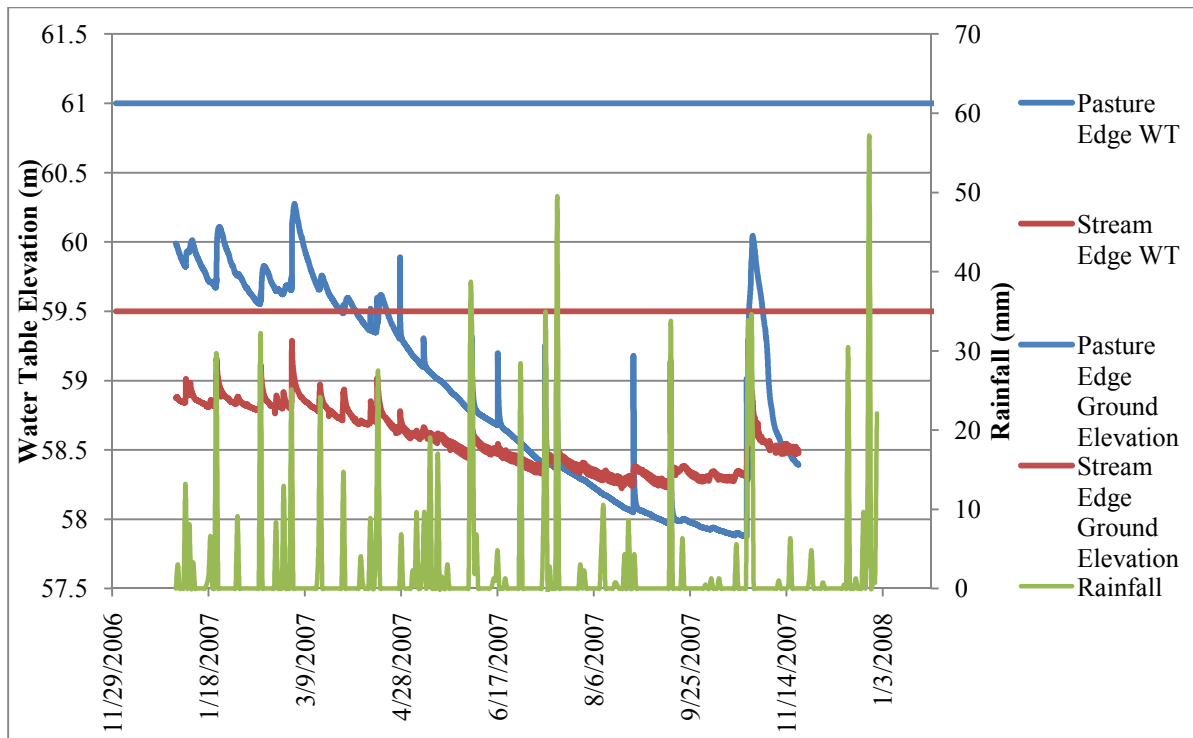


Figure 98. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2007.

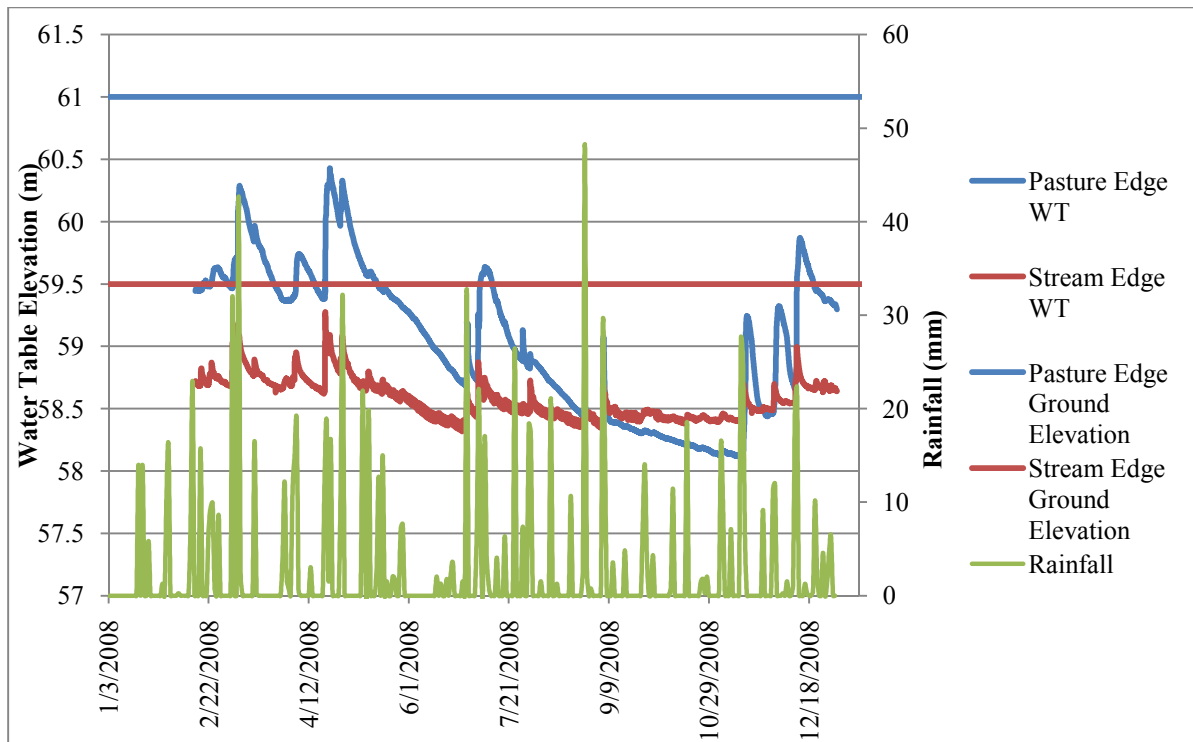


Figure 99. Block 2 water table elevations at the pasture edge and stream edge and rainfall amounts in 2008.

Block 2 Pasture Edge Redox

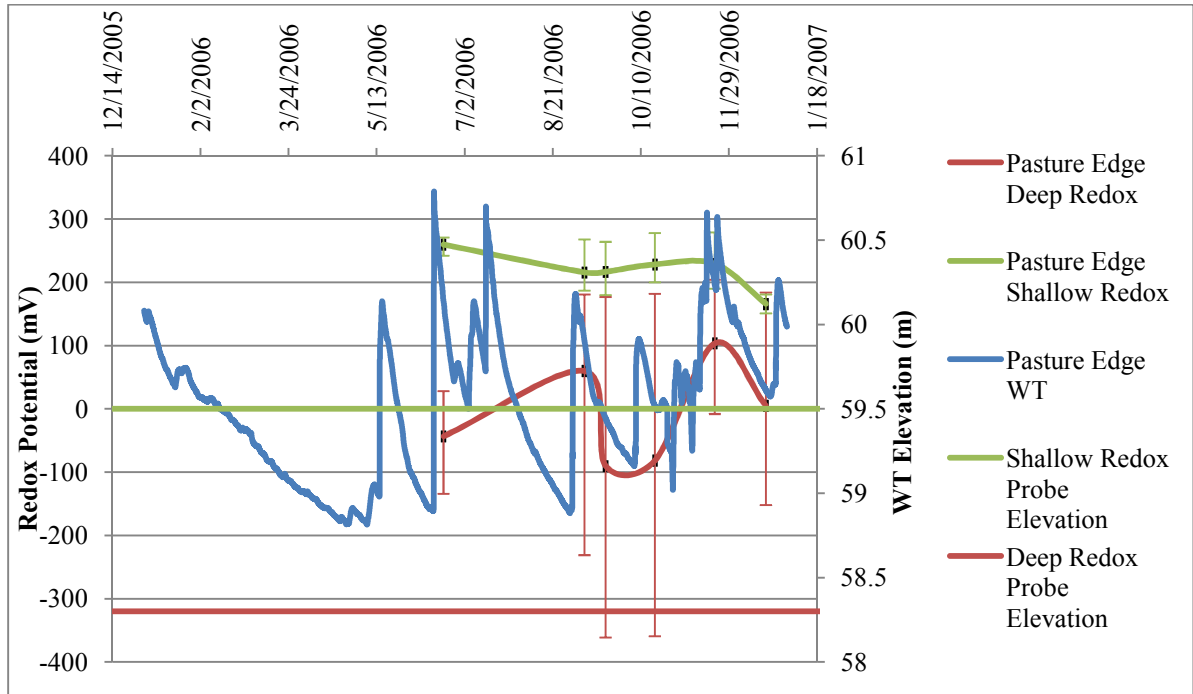


Figure 100. Mean pasture edge redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

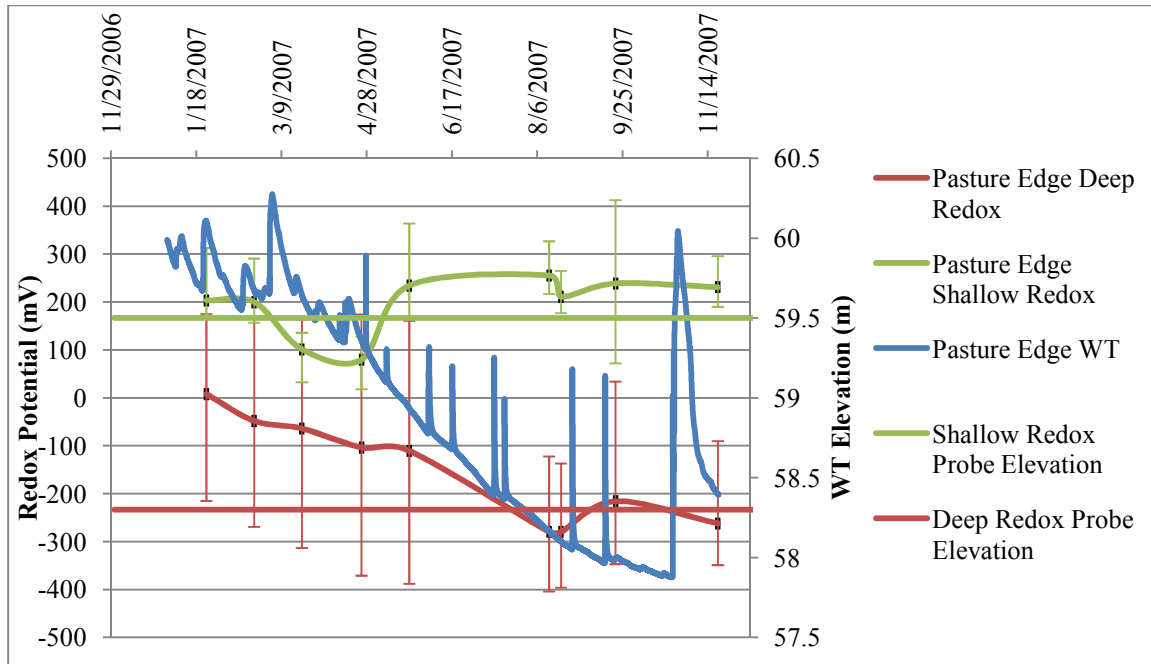


Figure 101. Mean pasture edge redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

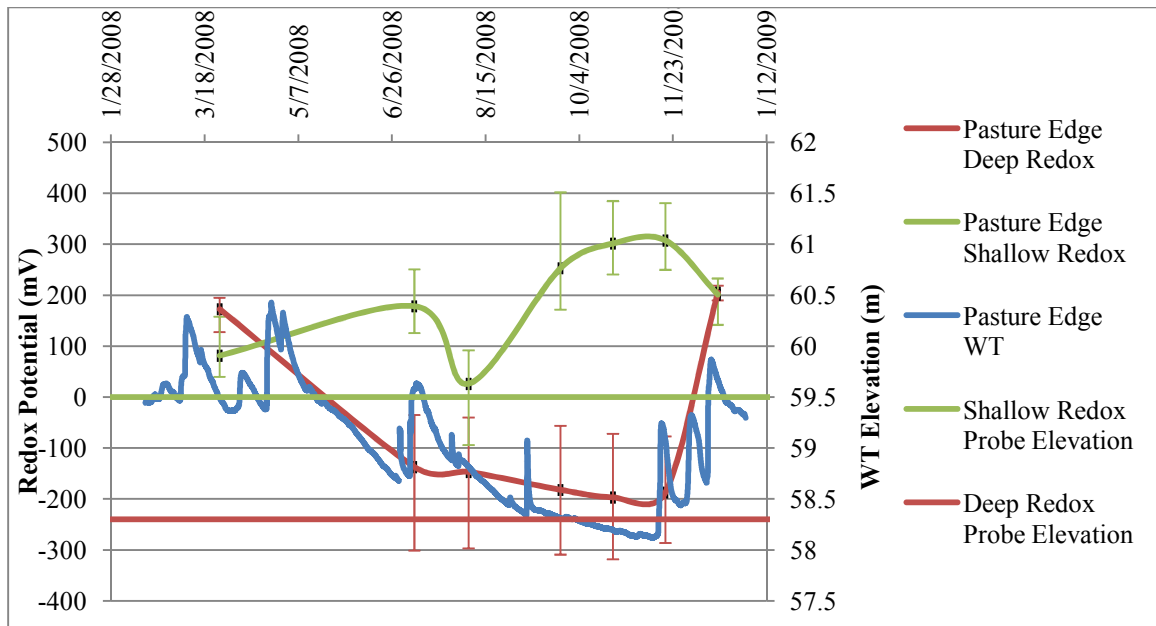


Figure 102. Mean pasture edge redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Block 2 Mid-buffer Redox

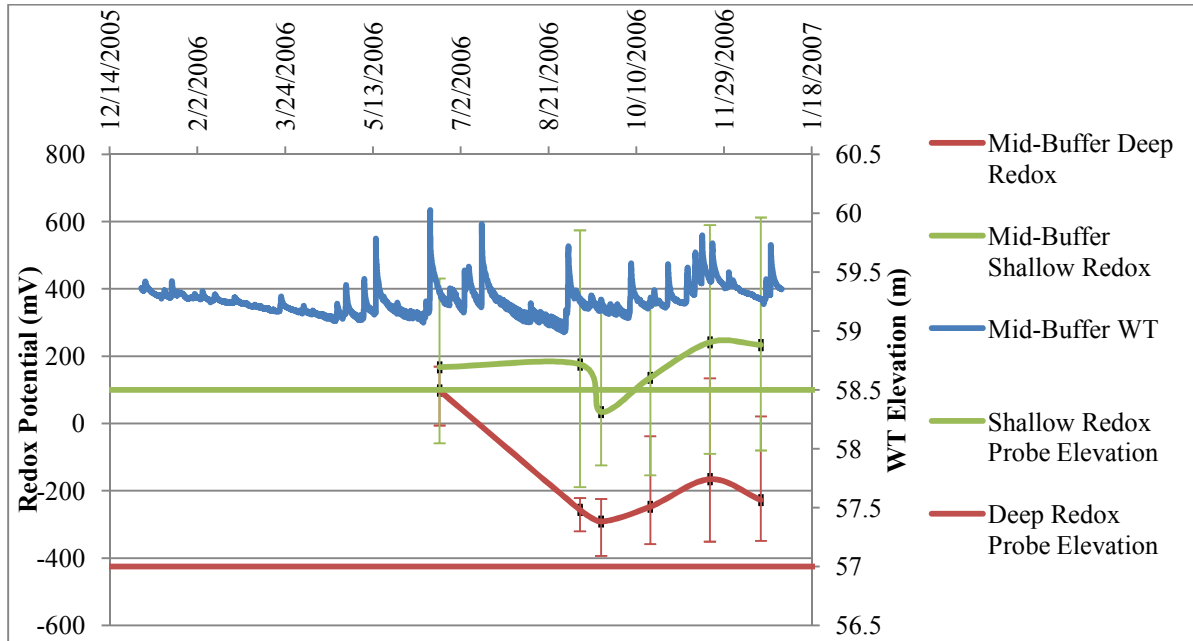


Figure 103. Mean mid-buffer redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

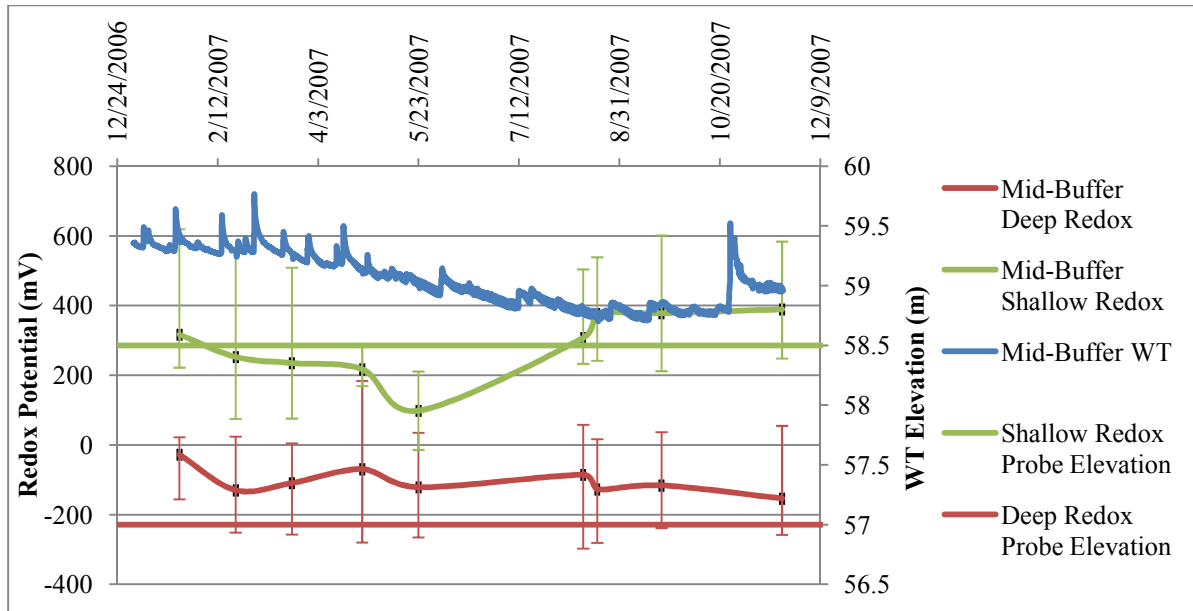


Figure 104. Mean mid-buffer redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

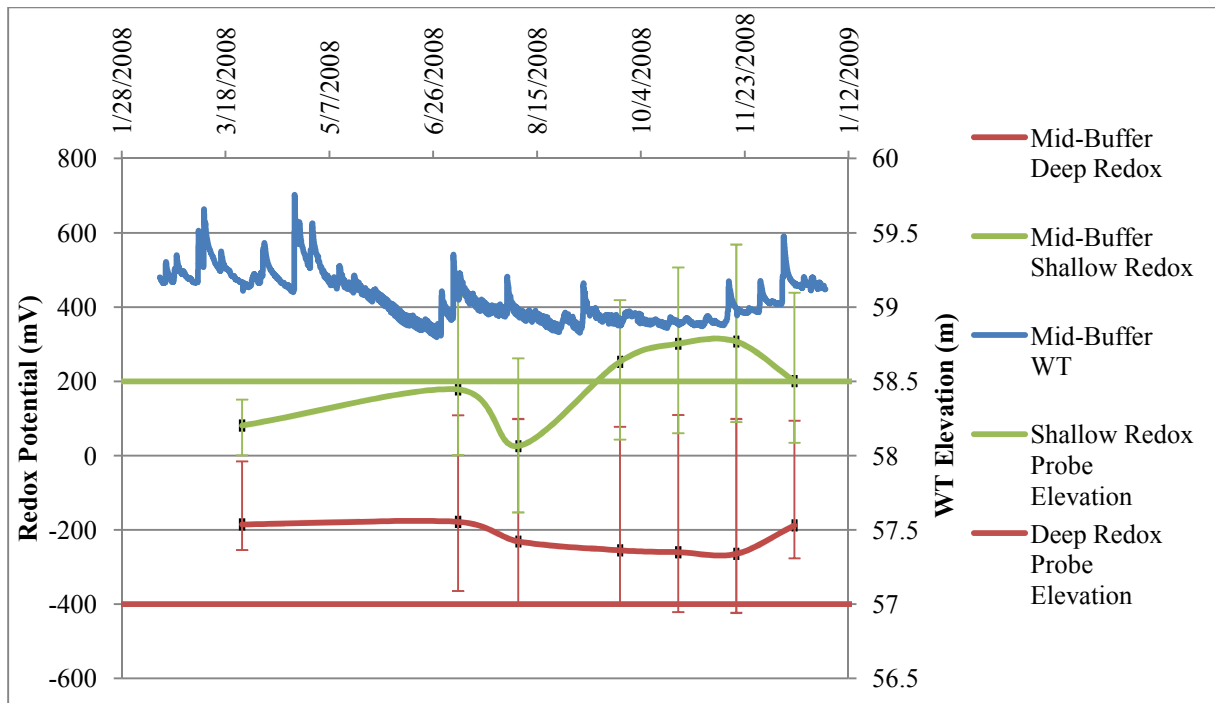


Figure 105. Mean mid-buffer redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Block 2 Stream Edge Redox

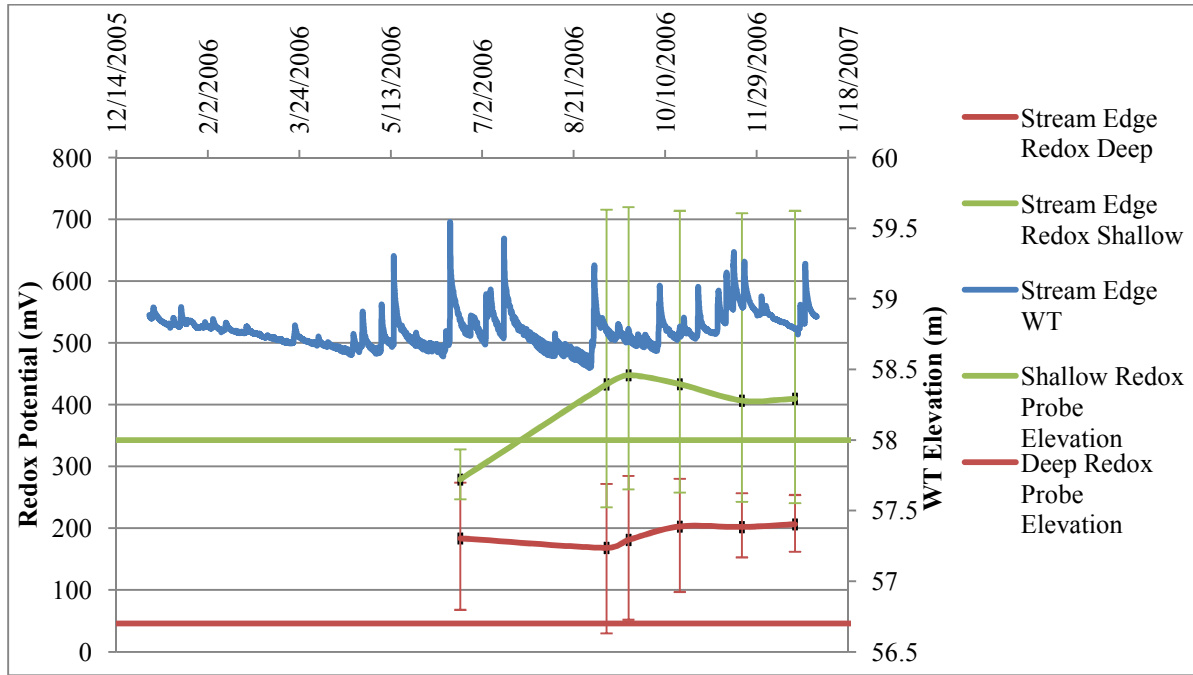


Figure 106. Mean stream edge redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

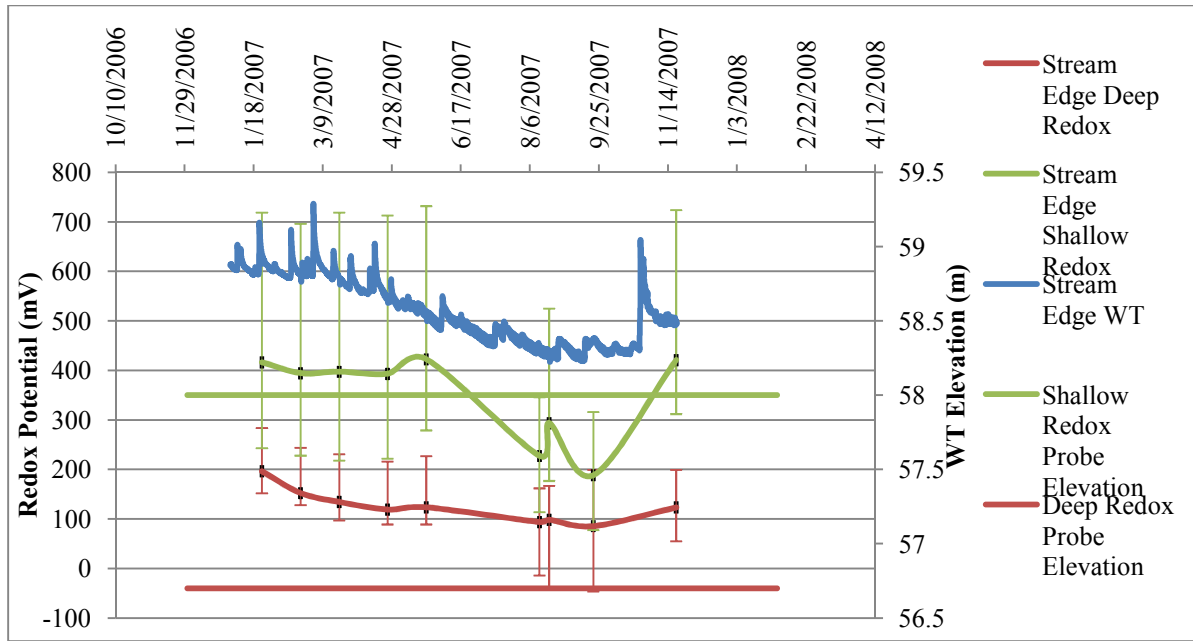


Figure 107. Mean stream edge redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

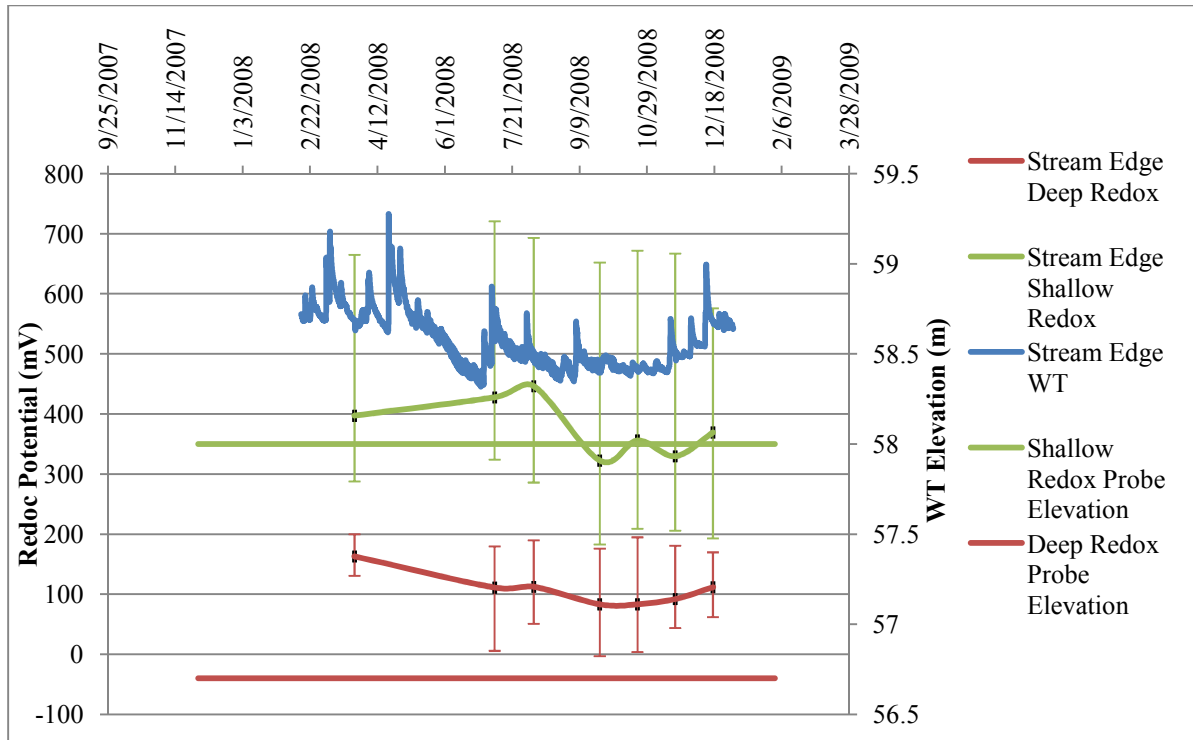


Figure 108. Mean stream edge redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Appendix C: Chapter 4 Supplemental (Block 3)

Block 3 Groundwater Hydrology

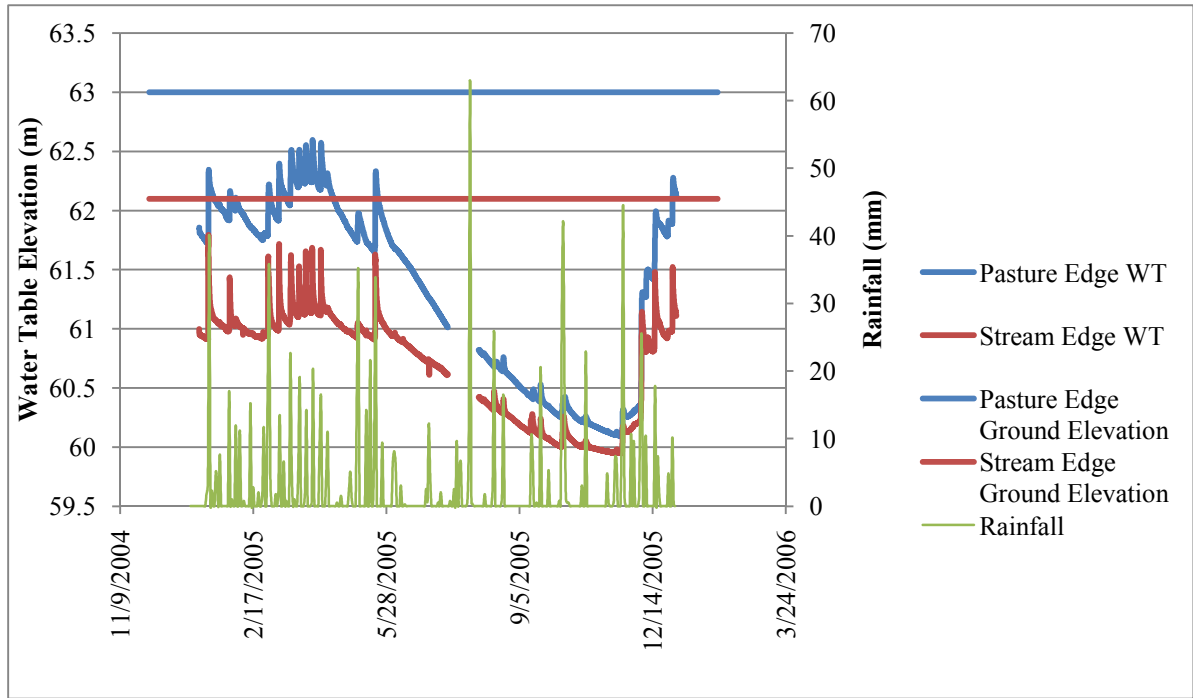


Figure 109. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2005.

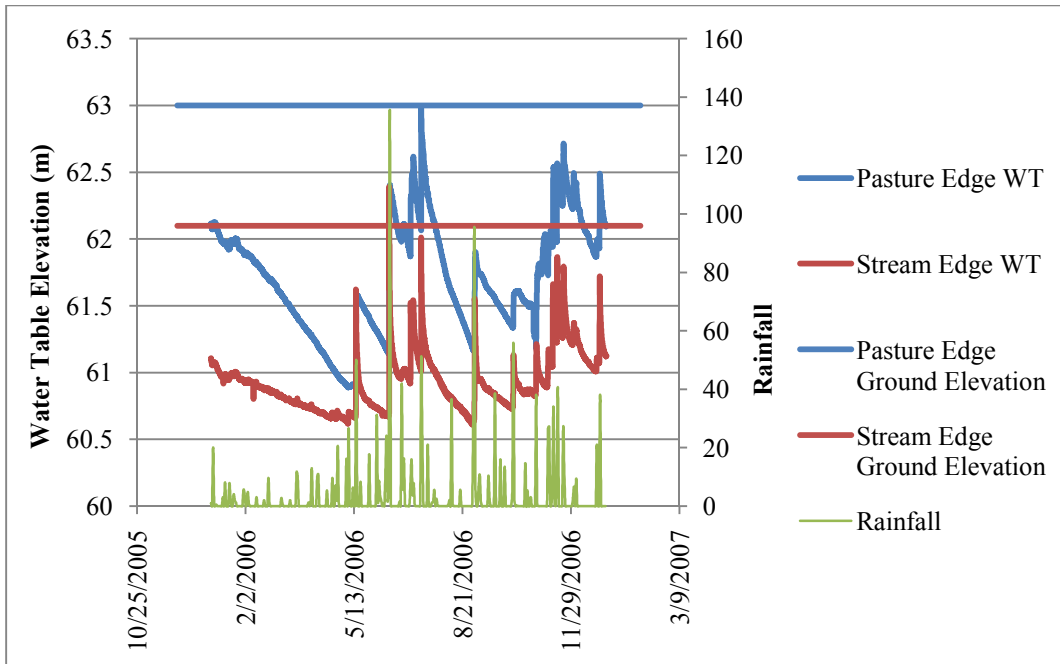


Figure 110. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2006.

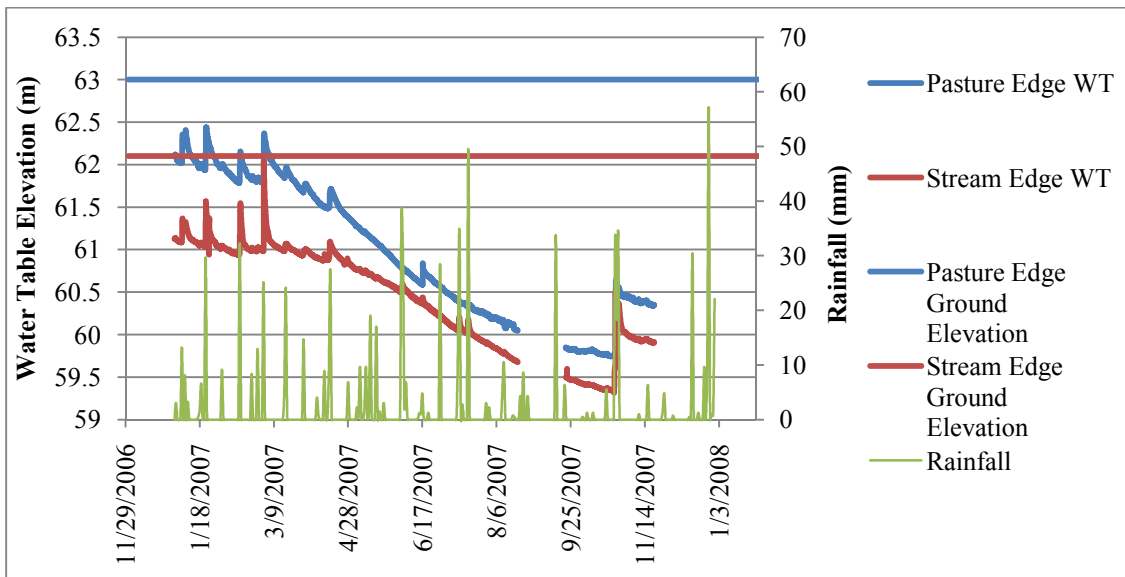


Figure 111. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2007.

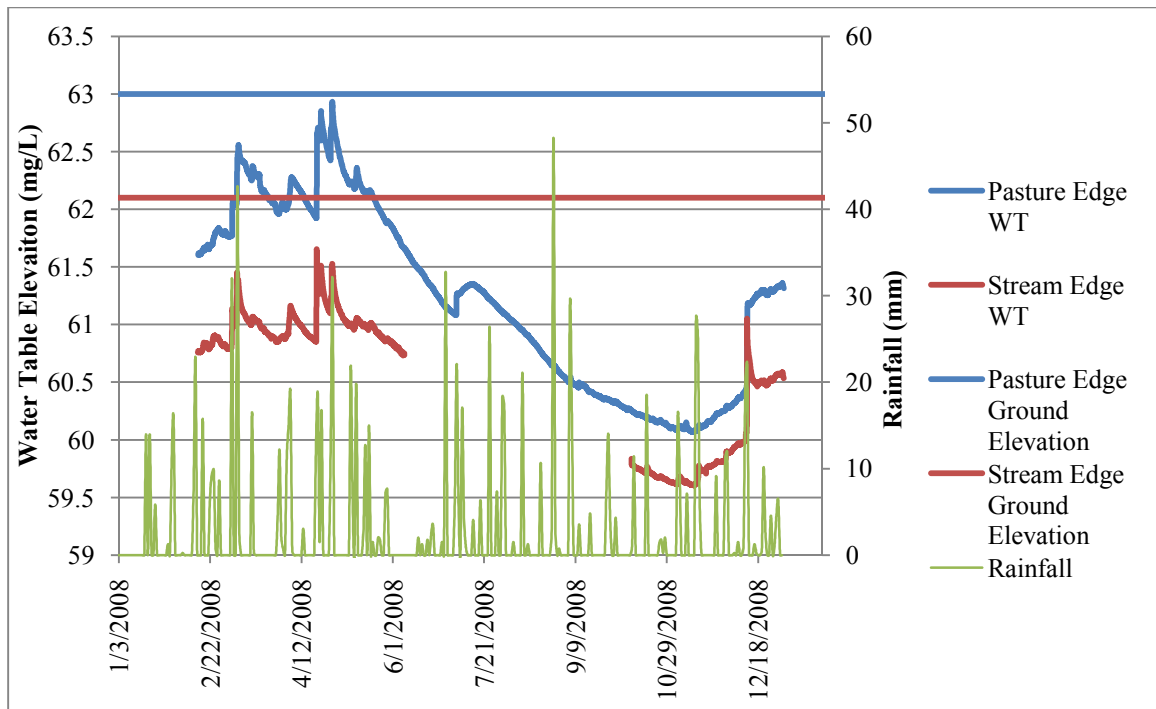


Figure 112. Block 3 water table elevations at the pasture edge and stream edge and rainfall amounts in 2008.

Block 3 Pasture Edge Redox

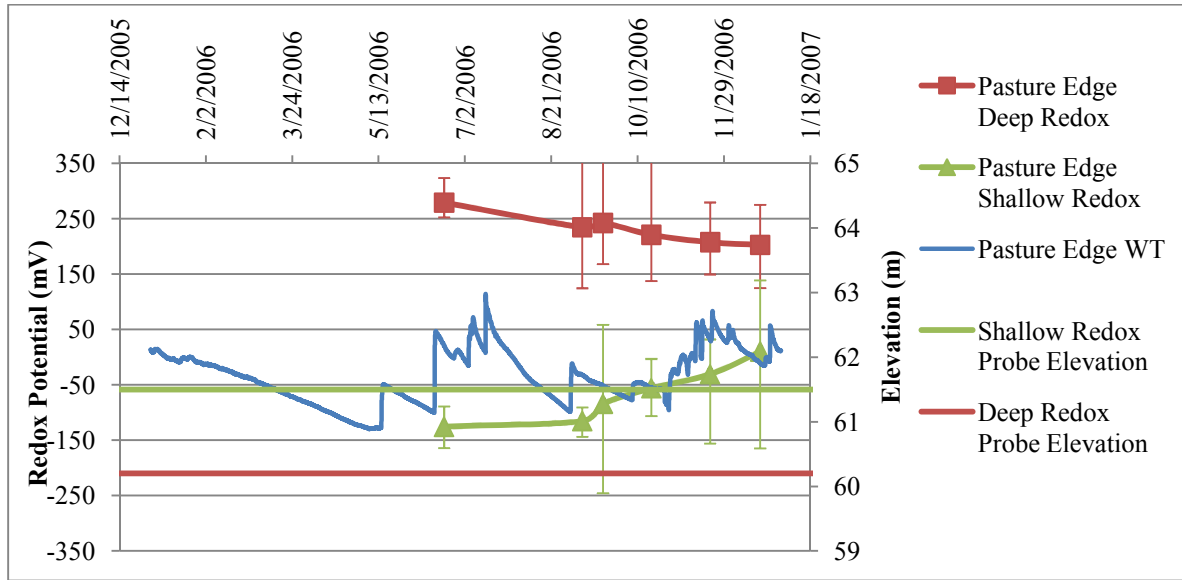


Figure 113. Mean pasture edge redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

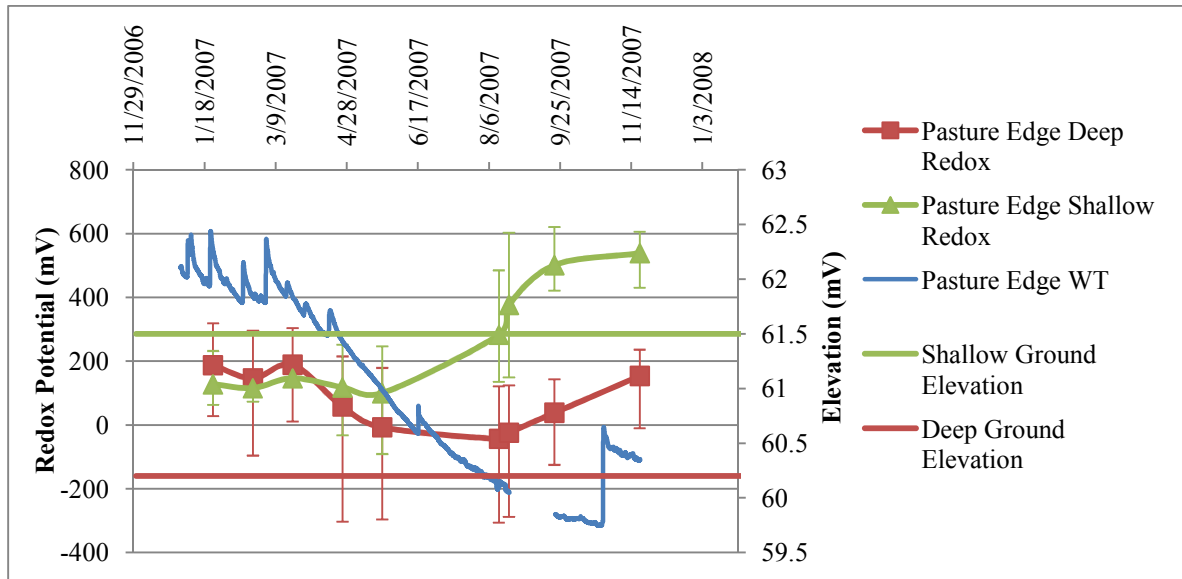


Figure 114. Mean pasture edge redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

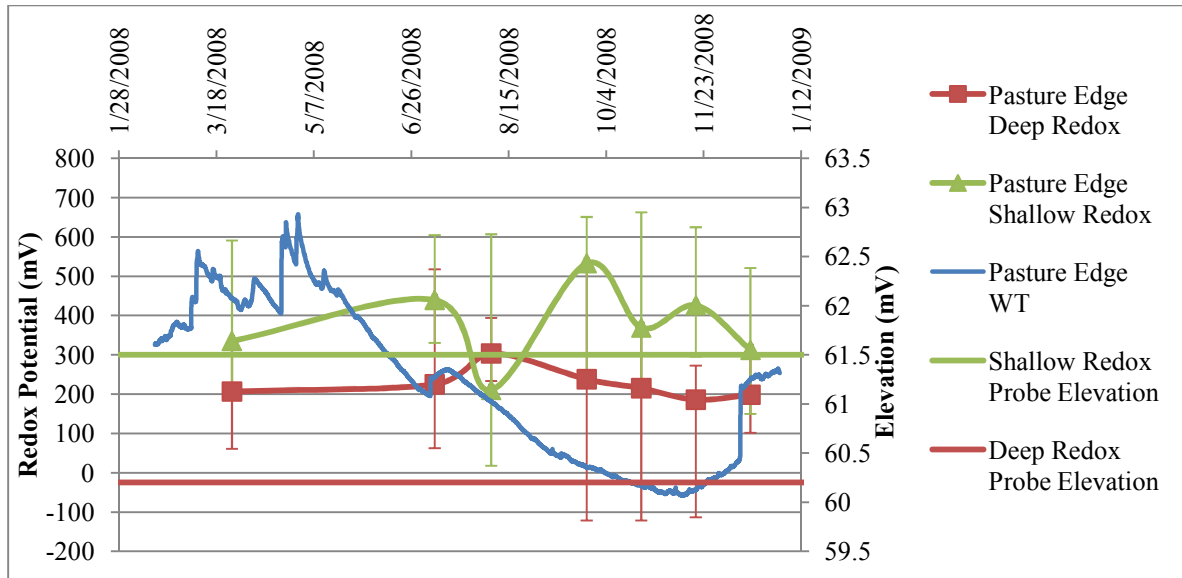


Figure 115. Mean pasture edge redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Block 3 Mid-buffer Redox

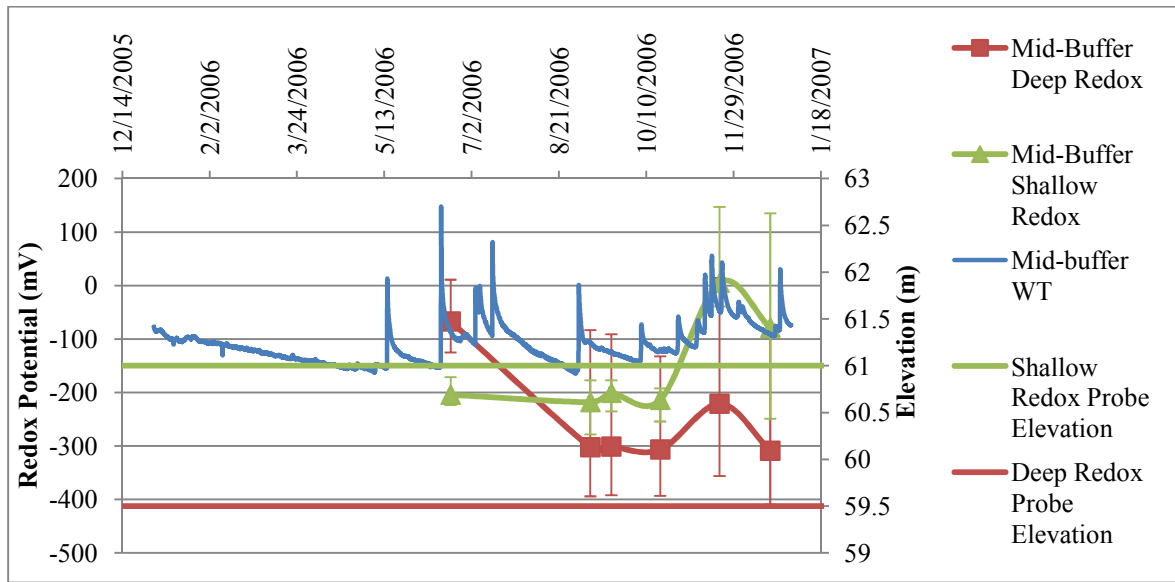


Figure 116. Mean mid-buffer redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

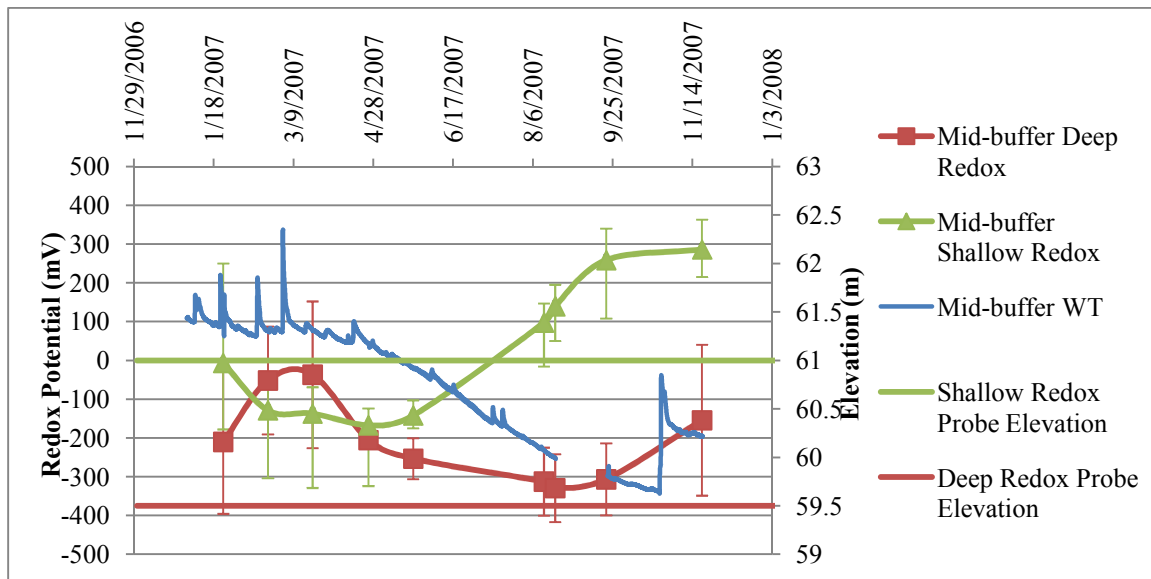


Figure 117. Mean mid-buffer redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

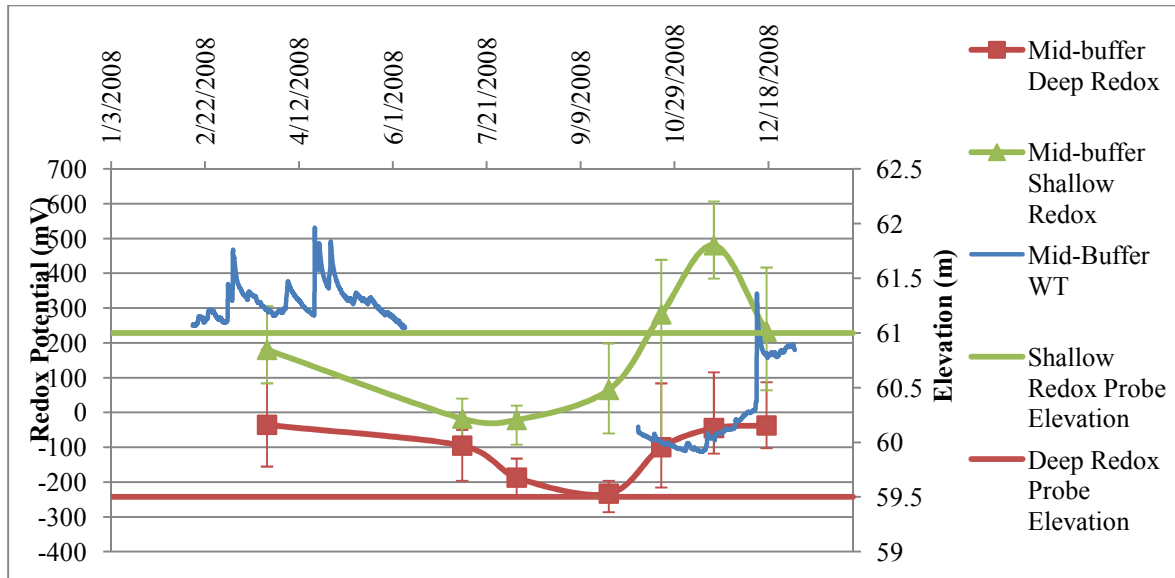


Figure 118. Mean mid-buffer redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Block 3 Stream Edge Redox

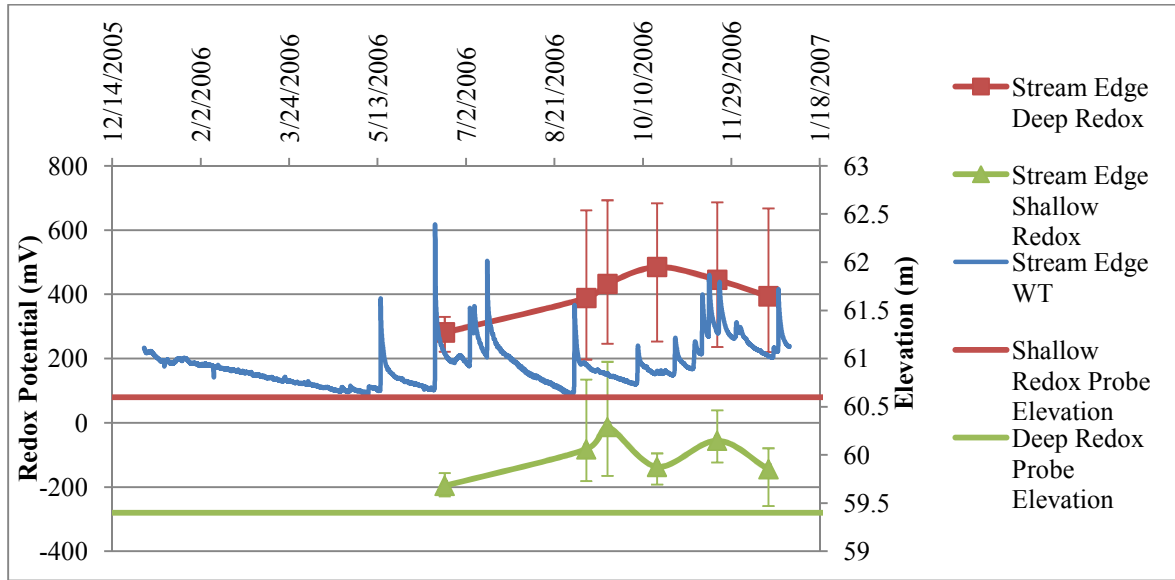


Figure 119. Mean stream edge redox potentials and water table elevations in 2006. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

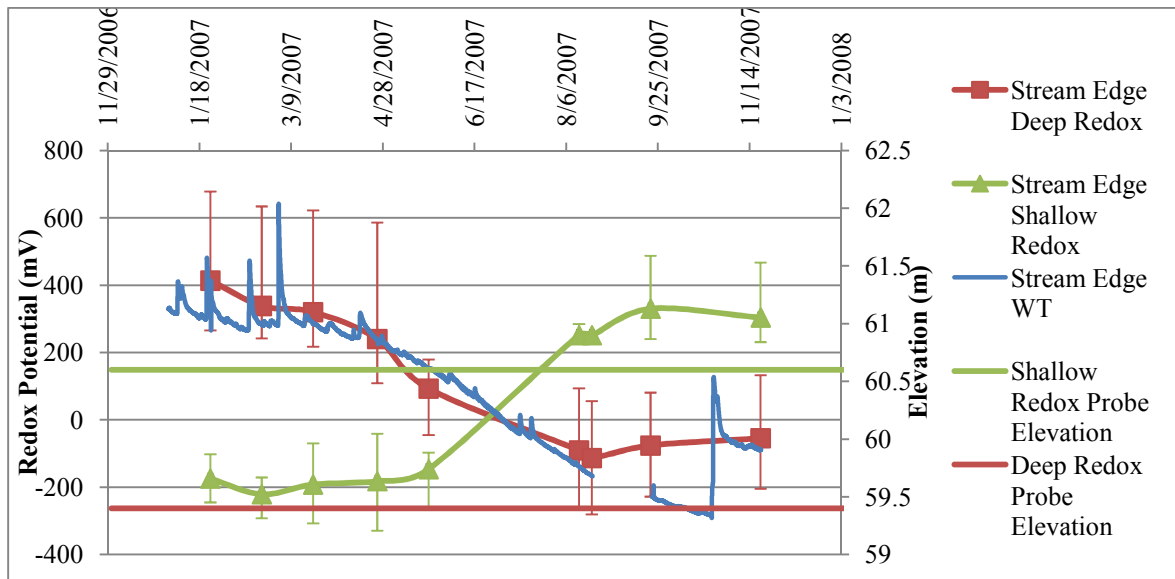


Figure 120. Mean stream edge redox potentials and water table elevations in 2007. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

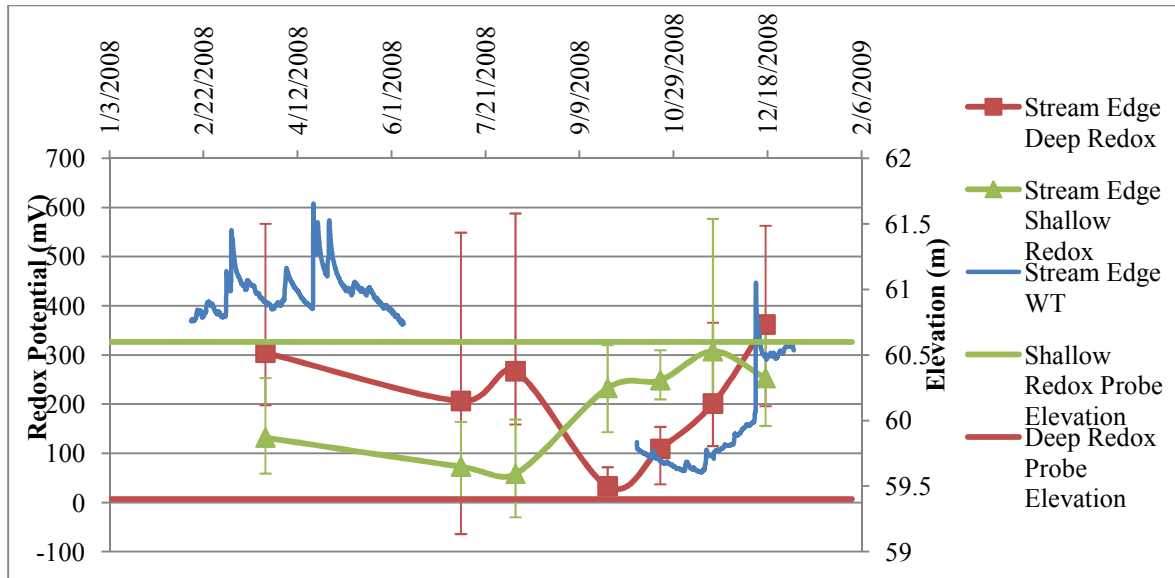


Figure 121. Mean stream edge redox potentials and water table elevations in 2008. Error bars represent the maximum and minimum readings recorded of the 5 probes at each location during sampling events.

Appendix D: Biological Removal Calculations

Groundwater mixing and subsequent dilution of NO₃-N concentrations was evident by the reductions in Cl⁻ concentrations between the pasture edge and stream edge in every monitoring block at the site. However, further analysis showed that the reduction in NO₃-N concentrations exceeded those found in Cl⁻ concentrations. This portion of the decrease in NO₃-N concentrations was thought to be the maximum amount of the NO₃-N reduction that could be attributed to biological removal.

The mean concentration at the pasture edge and stream edge was calculated for each sampling date for the analysis. First the difference in NO₃-N concentrations and Cl⁻ concentrations between the pasture edge groundwater and stream edge groundwater were calculated. The difference in NO₃-N concentrations ($\Delta \text{NO}_3\text{-N}$) was then subtracted from the difference in Cl⁻ concentrations (ΔCl^-). This difference was the maximum biological removal for that sampling date. If the ΔCl^- was greater than the $\Delta \text{NO}_3\text{-N}$ then the biological removal was set to zero. If NO₃-N concentration increased between the pasture edge and stream edge groundwater then a negative biological removal equal to the NO₃-N difference was inputted for the biological removal. The tables below show the calculations for individual dates.

Block 1

Table 19. Block 1 shallow 1.5 m (5 ft) groundwater depth estimated biological removal calculations

Sampling Date	Mean Pasture Edge Concentrations		Mean Stream Edge Concentrations		Difference in Pasture Edge and Stream Edge Concentrations		Biological Removal
	NO ₃ -N (mg/L)	Cl ⁻ (mg/L)	NO ₃ -N (mg/L)	Cl ⁻ (mg/L)	Δ NO ₃ -N (%)	Δ Cl ⁻ (%)	Δ NO ₃ -N - Δ Cl ⁻ (%)
4/6/2005	1.6	2.4	0.8	5.2	53.2	-111.6	53.2
4/20/2005	8.2	4.8	1.0	4.6	87.9	3.5	84.4
5/5/2005	9.2	2.2	1.4	3.2	84.8	-45.5	84.8
5/18/2005	10.1	5.8	1.2	6.5	88.3	-11.2	88.3
6/2/2005	13.5	12.1	1.4	5.0	89.4	58.7	30.8
6/15/2005	16.9	10.2	1.3	4.8	92.5	52.9	39.5
6/29/2005	1.9	3.5	1.0	5.0	46.1	-41.4	46.1
12/1/2005	16.5	31.5	1.4	4.2	91.5	86.7	4.8
6/8/2006	18.9	22.5	0.2	4.7	98.9	79.3	19.6
8/10/2006	12.7	15.0	1.3	8.7	89.7	42.3	47.4
9/20/2006	4.6	4.1	1.1	3.0	76.6	26.8	49.8
10/18/2006	5.4	2.7	1.1	3.0	79.9	-13.2	79.9
11/21/2006	18.8	16.5	0.5	2.1	97.3	87.6	9.8
12/20/2006	26.7	14.6	0.6	2.3	97.7	84.6	13.0
1/24/2007	15.3	10.0	0.5	3.1	96.7	69.0	27.7
2/21/2007	11.9	6.3	0.9	2.0	92.6	69.0	23.6
3/21/2007	8.1	3.8	0.7	2.4	91.6	36.0	55.6
4/1/2007	8.7	6.4	0.9	3.2	89.3	50.0	39.3
5/13/2008	12.7	4.8	2.5	3.6	80.5	26.0	54.4
6/10/2008	9.8	9.9	1.0	4.9	90.1	51.0	39.2
7/8/2008	6.4	2.8	1.1	4.3	82.5	-53.7	82.5
12/17/2008	13.1	3.5	1.1	6.1	91.7	-76.4	91.7
1/23/2009	14.5	16.8	1.6	9.3	88.9	44.6	44.3
2/17/2009	33.3	33.1	0.9	7.6	97.2	76.9	20.2
3/24/2009	15.2	6.1	0.7	4.8	95.2	21.4	73.8
4/21/2009	32.4	20.8	0.5	4.8	98.6	77.1	21.5
10/20/2009	7.6	27.4	1.6	6.3	78.7	76.9	1.8

11/17/2009	11.6	10.7	1.1	5.7	90.5	47.1	43.4
12/15/2009	14.6	6.5	0.7	6.3	94.9	3.8	91.1
1/19/2010	13.1	4.7	0.4	5.6	96.7	-20.1	96.7
2/18/2010	10.9	3.3	0.3	4.4	97.1	-33.0	97.1
3/16/2010	8.4	3.8	0.4	5.0	95.8	-32.5	95.8
4/22/2010	9.3	4.6	0.5	5.0	94.9	-8.7	94.9
Mean	12.8	10.1	1.0	4.7	88.4	21.9	52.9

Table 20. Block 1 Deep 3.0 m (10 ft) groundwater depth estimated biological removal calculations

Sampling Date	Mean Pasture Edge Concentrations		Mean Stream Edge Concentrations		Difference in Pasture Edge and Stream Edge Concentrations		Biological Removal
	NO ₃ -N (mg/L)	Cl ⁻ (mg/L)	NO ₃ -N (mg/L)	Cl ⁻ (mg/L)	Δ NO ₃ -N (%)	Δ Cl ⁻ (%)	Δ NO ₃ -N - Δ Cl ⁻ (%)
4/6/2005	5.6	10.9	1.0	1.8	81.6	83.5	0.0
4/20/2005	5.3	9.6	1.0	5.4	80.5	44.5	36.1
5/5/2005	5.1	3.3	1.0	2.4	80.8	28.0	52.8
5/18/2005	5.6	9.9	1.1	4.6	79.8	53.4	26.4
6/2/2005	5.7	10.8	1.3	6.7	77.8	37.8	40.0
6/15/2005	6.0	8.0	1.1	3.4	81.4	57.9	23.4
6/29/2005	6.3	8.2	1.2	3.6	81.4	56.5	24.9
7/13/2005	6.4	8.5	1.5	3.6	77.5	57.6	19.8
7/27/2005	6.7	12.0	1.9	7.2	71.4	40.2	31.3
8/10/2005	5.7	10.0	1.3	5.4	77.0	45.8	31.2
8/23/2005	6.2	10.5	1.3	5.6	78.5	46.8	31.7
9/29/2005	6.4	10.5	1.4	5.5	78.1	47.8	30.3
10/27/2005	6.0	10.2	1.4	5.6	76.0	45.8	30.2
12/1/2005	9.8	14.6	1.3	3.3	87.2	77.3	9.9
1/12/2006	11.7	17.9	1.4	4.1	88.3	77.3	11.0
2/9/2006	13.8	20.8	1.3	3.7	90.8	82.2	8.6
3/9/2006	14.0	21.1	1.4	6.2	90.2	70.8	19.4
4/13/2006	12.1	18.9	1.3	4.0	89.1	78.8	10.2
5/12/2006	11.3	16.2	1.3	3.3	88.7	79.7	9.0

6/8/2006	7.2	15.9	1.3	8.1	82.0	49.1	33.0
8/10/2006	10.8	15.5	1.2	3.4	88.6	78.4	10.2
9/20/2006	9.2	10.6	1.0	2.2	88.9	79.7	9.1
10/18/2006	9.2	9.8	1.2	1.8	87.2	82.1	5.1
11/21/2006	10.8	9.6	0.7	1.4	93.7	85.4	8.3
12/20/2006	11.7	11.0	1.0	1.5	91.2	86.3	4.9
1/24/2007	11.3	13.4	0.8	2.4	92.7	82.1	10.6
2/21/2007	10.7	10.1	1.1	2.2	89.7	78.8	10.9
3/21/2007	10.6	11.1	1.1	2.1	89.9	81.5	8.3
4/1/2007	10.8	10.6	1.1	2.5	89.6	76.9	12.7
5/1/2007	9.5	9.2	1.2	1.7	87.6	81.6	6.0
6/1/2007	8.7	8.5	0.9	1.3	89.4	84.6	4.7
7/1/2007	8.2	10.1	1.2	2.1	85.6	79.1	6.5
8/20/2007	8.5	9.9	1.8	3.2	79.1	68.3	10.8
9/17/2007	6.1	9.9	1.3	2.9	79.1	71.1	8.0
11/24/2007	21.0	10.4	1.4	1.9	93.4	82.2	11.2
5/13/2008	17.9	12.1	2.2	5.2	87.5	56.9	30.6
6/10/2008	14.0	11.6	1.0	3.4	92.9	70.7	22.1
7/8/2008	12.8	10.9	1.1	3.0	91.5	72.2	19.4
8/6/2008	11.2	11.7	1.3	4.1	88.7	65.0	23.7
9/24/2008	11.2	8.8	1.2	4.3	89.2	51.7	37.5
10/22/2008	12.9	7.9	1.3	4.4	90.1	44.4	45.7
11/19/2008	11.8	10.2	1.2	4.0	89.8	60.3	29.5
12/17/2008	15.1	10.5	1.2	4.4	91.9	57.9	34.0
1/23/2009	13.9	11.0	1.2	7.4	91.3	33.2	58.1
2/17/2009	14.0	10.2	1.1	5.3	92.1	48.1	44.1
3/24/2009	13.4	10.4	0.7	4.5	94.8	56.7	38.2
4/21/2009	13.0	10.1	0.8	3.5	94.0	64.9	29.1
5/28/2009	16.4	11.9	1.1	4.1	93.3	65.1	28.2
6/29/2009	18.7	12.6	1.2	4.3	93.6	66.3	27.3
7/21/2009	23.1	11.3	1.1	4.1	95.3	63.2	32.0
8/18/2009	17.3	10.4	1.3	4.2	92.5	59.6	32.9
9/15/2009	16.2	8.3	1.2	4.6	92.4	44.5	47.8
10/20/2009	14.6	10.7	1.3	4.8	91.3	55.4	35.9
11/17/2009	9.2	10.2	1.3	4.6	85.5	54.8	30.7
12/15/2009	15.0	9.1	1.0	5.6	93.6	38.9	54.7
1/19/2010	12.5	8.4	0.5	4.8	95.8	43.3	52.5

2/18/2010	14.2	9.3	0.4	3.5	97.1	62.1	35.1
3/16/2010	14.1	9.1	0.5	4.2	96.3	53.6	42.7
4/22/2010	12.9	8.9	0.7	4.1	94.8	54.7	40.1
5/18/2010	11.6	7.2	1.5	5.6	87.0	22.6	64.4
Mean	11.2	11.0	1.2	4.0	87.8	62.1	25.7

Block 2

Table 21. Block 2 Shallow 1.5 m (5 ft) groundwater depth estimated biological removal calculations

Sampling Date	Mean Pasture Edge Concentrations		Mean Stream Edge Concentrations		Difference in Pasture Edge and Stream Edge Concentrations		Biological Removal $\Delta \text{NO}_3\text{-N} - \Delta \text{Cl}^-$ (%)
	$\text{NO}_3\text{-N}$ (mg/L)	Cl^- (mg/L)	$\text{NO}_3\text{-N}$ (mg/L)	Cl^- (mg/L)	$\Delta \text{NO}_3\text{-N}$ (%)	ΔCl^- (%)	
4/6/2005	1.1	3.2	1.7	3.9	-60.0	-20.6	0.0
4/20/2005	4.5	4.6	2.0	4.1	54.9	9.5	45.4
5/5/2005	4.3	5.1	2.0	3.6	53.1	30.1	23.0
5/18/2005	4.4	9.3	2.5	4.9	44.7	47.5	0.0
6/2/2005	4.2	9.5	2.4	5.2	42.9	45.3	0.0
6/15/2005	5.8	4.9	2.2	3.5	61.4	29.3	32.2
6/29/2005	2.5	7.2	2.4	3.5	2.6	51.2	0.0
7/13/2005	4.8	5.1	2.3	3.5	52.1	31.4	20.7
12/1/2005	5.1	5.5	2.1	3.6	59.8	33.9	25.9
1/12/2006	8.0	18.7	2.0	4.0	75.6	78.6	0.0
2/9/2006	7.1	17.7	2.4	3.8	66.0	78.8	0.0
3/9/2006	7.5	17.1	2.3	4.5	68.9	73.5	0.0
4/13/2006	8.0	19.9	2.0	3.2	74.7	83.8	0.0
5/12/2006	11.6	17.4	1.9	2.9	83.5	83.5	0.0
6/8/2006	5.9	14.7	1.6	5.2	73.0	64.5	8.5
8/10/2006	4.7	17.9	1.6	2.7	65.8	85.1	0.0
9/20/2006	3.6	9.1	1.2	1.7	67.5	81.4	0.0
10/18/2006	3.3	8.3	1.4	1.7	58.7	79.2	0.0
11/21/2006	7.7	7.2	2.0	1.6	73.9	77.7	0.0
12/20/2006	7.2	6.8	2.4	2.0	66.8	70.7	0.0
1/24/2007	7.7	9.0	1.6	2.8	79.0	68.8	10.2
2/21/2007	7.0	7.5	1.9	3.2	72.8	56.9	15.9
3/21/2007	6.5	7.6	1.9	2.3	70.9	69.3	1.6
4/1/2007	5.1	9.1	2.4	2.4	53.8	73.3	0.0
5/1/2007	6.5	6.7	2.0	1.7	69.3	75.0	0.0
11/24/2007	8.2	5.9	1.6	1.9	81.0	67.8	13.2
4/22/2008	11.2	24.7	1.1	16.6	89.8	33.1	56.8
5/13/2008	19.8	8.2	1.1	5.6	94.6	32.2	62.4
6/10/2008	10.6	11.4	1.0	4.4	90.7	61.4	29.3

7/8/2008	8.9	7.9	1.3	2.9	85.9	62.7	23.2
8/6/2008	10.0	11.2	1.7	4.0	83.4	63.9	19.6
12/17/2008	11.5	8.5	2.2	5.1	81.0	40.3	40.7
1/23/2009	9.9	22.2	1.8	14.2	82.1	35.9	46.2
3/24/2009	11.2	8.2	3.1	5.4	72.7	34.6	38.1
4/21/2009	9.6	7.9	1.9	5.0	80.4	36.8	43.6
9/15/2009	0.4	12.0	1.7	4.6	-354.1	61.6	0.0
11/17/2009	10.9	7.2	2.6	4.7	76.0	34.0	42.0
12/15/2009	6.6	7.3	2.6	6.6	60.6	9.7	50.9
1/19/2010	9.2	7.7	2.5	5.9	73.4	23.4	50.0
2/18/2010	9.1	7.7	3.2	9.0	64.7	-17.7	82.4
3/16/2010	9.2	7.8	3.1	6.4	66.1	17.9	48.2
4/22/2010	8.9	8.1	2.8	5.3	68.9	34.4	34.5
5/18/2010	8.7	7.5	2.9	5.2	67.0	31.3	35.7
Mean	7.4	10.0	2.0	4.5	55.7	49.3	20.9

Table 22. Block 2 deep 3.0 m (10 ft) groundwater depth estimated biological removal calculations

Sampling Date	Mean Pasture Edge Concentrations		Mean Stream Edge Concentrations		Difference in Pasture Edge and Stream Edge Concentrations		Biological Removal
	NO ₃ -N (mg/L)	Cl ⁻ (mg/L)	NO ₃ -N (mg/L)	Cl ⁻ (mg/L)	Δ NO ₃ -N (%)	Δ Cl ⁻ (%)	Δ NO ₃ -N - Δ Cl ⁻ (%)
4/6/2005	5.1	6.6	1.4	2.6	72.9	60.1	12.8
4/20/2005	4.7	5.3	1.2	2.4	74.5	53.8	20.7
5/5/2005	4.6	6.3	1.1	4.2	75.3	33.7	41.6
5/18/2005	4.9	8.2	1.2	3.6	75.8	56.7	19.1
6/2/2005	4.9	8.7	1.3	3.4	73.9	61.5	12.5
6/15/2005	4.6	6.7	1.2	2.3	74.6	65.2	9.4
6/29/2005	4.9	6.7	1.2	2.3	74.5	65.8	8.7
7/13/2005	4.8	7.2	1.5	2.3	69.1	68.2	0.9
7/27/2005	4.3	10.6	1.6	5.6	63.8	47.0	16.8
8/10/2005	4.7	9.1	1.3	3.9	72.7	57.5	15.1
8/23/2005	4.9	9.5	1.3	3.9	73.7	59.2	14.6
9/29/2005	5.2	9.6	1.4	4.0	73.6	58.2	15.4
10/27/2005	5.0	9.3	1.4	4.1	71.1	55.4	15.7

12/1/2005	3.4	8.3	1.0	2.2	70.9	73.0	0.0
1/12/2006	7.5	19.1	1.4	2.5	81.8	86.9	0.0
2/9/2006	7.0	16.3	1.5	2.3	78.2	85.7	0.0
3/9/2006	5.9	13.5	1.1	3.9	80.8	71.3	9.5
4/13/2006	5.0	10.5	1.1	3.0	78.3	71.4	6.9
5/12/2006	6.5	13.1	1.1	1.9	83.8	85.2	0.0
6/8/2006	4.5	12.4	1.2	2.2	72.5	82.3	0.0
8/10/2006	5.7	12.8	1.3	2.4	76.9	81.5	0.0
9/20/2006	4.8	9.6	1.0	2.1	79.2	78.1	1.0
10/18/2006	4.5	9.2	1.2	1.1	74.0	88.4	0.0
11/21/2006	6.7	8.9	1.3	1.0	81.0	89.1	0.0
12/20/2006	7.8	9.4	1.3	0.7	82.9	92.9	0.0
1/24/2007	9.3	9.7	1.2	1.8	86.6	81.4	5.2
2/21/2007	7.7	7.6	1.3	1.0	83.8	86.8	0.0
3/21/2007	7.3	8.0	1.1	1.0	85.1	87.6	0.0
4/1/2007	7.3	8.4	1.3	1.8	82.6	78.2	4.4
5/1/2007	7.5	8.2	1.3	0.9	83.2	88.6	0.0
6/1/2007	7.2	7.2	1.3	0.8	81.9	88.9	0.0
7/1/2007	7.1	9.3	1.3	1.1	81.9	87.8	0.0
8/20/2007	6.9	9.3	1.4	1.8	79.8	80.7	0.0
9/17/2007	7.1	9.6	1.5	1.8	78.2	81.2	0.0
10/24/2007	6.2	8.2	1.4	1.6	76.7	80.8	0.0
11/24/2007	10.9	7.6	1.5	0.7	86.4	90.8	0.0
4/22/2008	8.7	28.1	0.9	17.9	89.4	36.3	53.0
5/13/2008	20.5	8.9	2.0	3.4	90.4	61.3	29.2
6/10/2008	7.9	10.5	1.0	3.2	87.5	69.0	18.5
7/8/2008	7.1	7.1	1.2	1.4	83.1	80.1	3.0
8/6/2008	7.9	9.6	1.2	3.3	85.2	65.7	19.5
9/24/2008	7.9	9.9	1.4	3.5	81.7	65.1	16.6
10/22/2008	8.2	10.1	1.4	3.4	83.2	66.2	17.0
11/19/2008	8.8	9.6	1.7	2.2	80.9	77.7	3.2
12/17/2008	12.1	11.3	1.3	3.3	89.3	70.4	19.0
1/23/2009	11.0	24.3	1.3	7.6	88.2	68.7	19.5
2/17/2009	9.8	9.8	1.2	3.1	87.4	68.5	18.9
3/24/2009	13.8	9.1	1.4	2.8	90.2	69.5	20.7
4/21/2009	10.9	8.7	1.1	2.9	89.7	66.8	22.9
5/28/2009	10.7	9.5	1.3	2.5	87.8	73.7	14.0
6/29/2009	10.4	9.6	1.4	4.0	86.8	58.3	28.5

7/21/2009	11.1	9.8	1.5	2.9	86.3	70.3	16.0
8/18/2009	10.2	9.4	1.4	3.4	86.0	64.1	21.9
9/15/2009	10.1	9.6	1.7	3.8	83.3	60.2	23.1
10/20/2009	7.5	10.2	1.8	3.9	76.4	61.4	14.9
11/17/2009	13.8	6.2	1.8	2.8	87.2	55.9	31.3
12/15/2009	9.6	9.0	1.4	3.9	85.4	56.2	29.1
1/19/2010	8.6	7.9	1.2	3.2	85.8	59.3	26.6
2/18/2010	7.6	7.4	1.2	3.1	84.2	57.7	26.4
3/16/2010	7.7	7.7	1.1	3.2	85.6	57.9	27.7
4/22/2010	8.4	7.5	1.2	3.0	85.6	59.3	26.3
5/18/2010	9.0	8.3	1.2	3.7	87.0	55.0	31.9
Mean	7.7	9.8	1.3	3.0	81.1	69.6	13.1

Block 3

Table 23. Block 3 Shallow 1.5 m (5 ft) groundwater depth estimated biological removal calculations

Sampling Date	Mean Pasture Edge Concentrations		Mean Stream Edge Concentrations		Difference in Pasture Edge and Stream Edge Concentrations		Biological Removal
	NO ₃ -N	Cl ⁻	NO ₃ -N	Cl ⁻	Δ NO ₃ -N	Δ Cl ⁻	Δ NO ₃ -N - Δ Cl ⁻
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(%)	(%)	(%)
4/6/2005	3.0	2.8	1.1	4.8	62.2	-70.6	62.2
4/20/2005	4.8	4.1	0.2	7.8	96.0	-91.8	96.0
5/5/2005	4.4	18.6	0.3	16.7	93.2	9.9	83.3
5/18/2005	4.6	5.0	0.4	4.4	91.9	10.7	81.1
6/2/2005	4.4	4.0	0.4	3.6	90.4	10.1	80.3
6/15/2005	5.3	4.3	0.3	3.4	93.8	21.7	72.1
6/29/2005	2.0	3.5	0.3	4.1	83.3	-18.3	83.3
7/13/2005	2.6	5.2	0.3	3.2	86.4	38.5	47.9
1/12/2006	3.5	28.2	0.3	6.9	91.1	75.7	15.4
2/9/2006	5.5	24.5	0.4	4.0	93.0	83.7	9.3
3/9/2006	5.5	20.0	0.3	6.6	94.0	66.8	27.2
4/13/2006	6.0	19.0	0.6	3.7	89.3	80.5	8.8
6/8/2006	4.2	26.9	0.2	4.6	95.0	82.8	12.2
8/10/2006	1.3	19.5	0.7	3.3	45.7	83.2	0.0

9/20/2006	3.4	14.0	0.1	2.2	97.5	84.2	13.3
10/18/2006	4.3	13.3	0.2	1.7	96.4	87.2	9.2
11/21/2006	3.9	12.4	0.5	2.0	87.2	84.1	3.1
12/20/2006	3.7	11.9	0.7	1.7	80.8	85.4	0.0
1/24/2007	5.2	14.6	0.9	2.9	82.4	79.9	2.5
2/21/2007	6.1	11.5	0.8	1.9	87.1	83.1	4.0
3/21/2007	5.9	10.2	0.8	2.2	85.6	78.0	7.7
4/1/2007	5.1	11.9	0.6	2.7	88.8	77.6	11.2
5/1/2007	3.5	12.2	0.5	2.0	84.6	83.3	1.2
4/22/2008	8.4	9.4	1.9	13.8	77.9	-47.5	77.9
5/13/2008	6.6	8.4	0.9	5.4	86.3	35.9	50.4
6/10/2008	4.8	10.4	1.0	6.1	79.9	41.6	38.3
7/8/2008	7.1	9.6	1.0	3.4	85.8	64.7	21.0
8/6/2008	5.4	13.1	1.0	4.5	80.9	66.0	14.9
12/17/2008	2.3	7.0	3.3	5.4	-40.0	22.3	0.0
1/23/2009							
2/17/2009	7.7	10.0	2.3	5.6	70.0	44.4	25.6
3/24/2009	7.5	8.4	3.2	4.7	56.7	44.6	12.1
4/21/2009	6.5	9.1	1.0	5.0	84.1	44.9	39.1
5/28/2009	6.9	9.8	1.4	4.9	80.0	50.3	29.8
11/17/2009	9.1	5.0	1.1	5.9	88.4	-18.3	88.4
12/15/2009	5.9	6.0	0.6	6.2	90.2	-3.1	93.4
1/19/2010	4.5	5.8	1.2	4.7	74.2	18.9	55.2
2/18/2010	4.0	5.8	0.7	4.7	82.1	19.1	63.1
3/16/2010	3.9	6.3	0.7	4.9	80.7	22.5	58.3
4/22/2010	4.1	7.2	0.6	5.8	85.6	20.4	65.3
5/18/2010	5.8	7.8	0.5	5.2	91.0	32.4	58.6
Mean	5.0	10.9	0.8	4.8	81.2	39.6	38.1

Table 24. Block 3 deep 3.0 m (10 ft) groundwater depth estimated biological removal calculations

Sampling Date	Mean Pasture Edge Concentrations		Mean Stream Edge Concentrations		Difference in Pasture Edge and Stream Edge Concentrations		Biological Removal $\Delta \text{NO}_3\text{-N} - \Delta \text{Cl}^-$ (%)
	$\text{NO}_3\text{-N}$ (mg/L)	Cl^- (mg/L)	$\text{NO}_3\text{-N}$ (mg/L)	Cl^- (mg/L)	$\Delta \text{NO}_3\text{-N}$ (%)	ΔCl^- (%)	

4/6/2005	3.9	4.5	2.2	2.5	44.6	43.3	1.3
4/20/2005	4.7	6.3	1.5	3.8	68.9	39.9	29.0
5/5/2005	4.6	12.6	1.3	27.5	73.0	-117.4	73.0
5/18/2005	5.1	6.4	1.6	4.2	68.2	34.6	33.7
6/2/2005	4.9	4.9	1.5	3.0	69.3	38.1	31.2
6/15/2005	5.1	4.6	1.6	2.8	69.2	38.4	30.7
6/29/2005	5.1	4.7	1.6	3.1	69.3	34.8	34.5
7/13/2005	5.3	4.6	1.6	2.9	69.2	36.2	33.0
7/27/2005	5.1	8.3	1.5	6.0	70.1	27.4	42.7
8/10/2005	5.2	6.7	1.5	4.7	70.9	29.7	41.2
8/23/2005	5.8	7.3	1.6	4.7	73.0	35.3	37.7
9/29/2005	6.0	8.7	1.7	4.8	72.2	44.7	27.6
10/27/2005	7.1	8.5	1.8	5.0	74.2	40.4	33.7
12/1/2005	6.0	5.7	1.8	3.2	69.8	44.2	25.6
1/12/2006	4.8	5.2	1.7	3.3	65.0	36.5	28.5
2/9/2006	4.8	5.8	1.7	3.1	65.3	46.8	18.5
3/9/2006	4.4	7.6	1.5	4.7	64.7	37.9	26.8
4/13/2006	4.1	10.5	1.4	3.4	66.3	67.4	0.0
5/12/2006	4.1	11.8	1.6	2.7	61.3	76.8	0.0
6/8/2006	4.1	19.4	1.5	5.4	61.9	72.0	0.0
8/10/2006	4.8	23.2	1.4	3.0	70.5	87.2	0.0
9/20/2006	4.7	19.0	0.9	1.9	81.3	90.2	0.0
10/18/2006	4.6	17.5	1.0	1.4	78.2	92.0	0.0
11/21/2006	4.7	16.9	1.6	1.6	67.0	90.7	0.0
12/20/2006	4.8	14.4	1.2	1.1	75.5	92.6	0.0
1/24/2007	5.1	14.3	1.3	2.5	75.1	82.5	0.0
2/21/2007	6.0	11.5	1.1	1.7	82.2	85.2	0.0
3/21/2007	5.8	11.6	0.9	1.7	83.9	85.1	0.0
4/1/2007	5.4	12.5	0.9	2.4	84.2	80.9	3.3
5/1/2007	2.9	10.8	0.8	1.9	70.9	82.7	0.0
6/1/2007	5.0	10.2	0.8	2.0	83.5	80.8	2.8
7/1/2007	5.0	12.0	1.0	2.9	79.7	75.9	3.8
8/20/2007	6.3	12.1	1.1	3.1	83.3	74.4	9.0
9/17/2007	10.7	12.9	1.2	3.8	88.9	70.5	18.3
10/24/2007	10.3	13.3	1.3	3.7	87.8	72.2	15.6
11/24/2007	5.3	10.4	1.3	2.6	75.8	74.8	1.0
4/22/2008	11.8	12.1	1.4	8.0	88.4	33.8	54.7
5/13/2008	11.1	11.9	1.1	4.8	89.8	59.8	30.0

6/10/2008	9.0	13.0	1.1	5.2	88.1	59.7	28.3
7/8/2008	7.9	10.8	1.2	3.3	85.0	69.3	15.7
8/6/2008	7.0	12.0	1.3	6.4	82.1	47.0	35.1
9/24/2008	6.5	13.2	2.2	7.5	65.6	43.7	22.0
10/22/2008	7.6	6.1	3.0	0.0	60.8	100.0	0.0
11/19/2008	7.8	11.0	2.7	7.7	65.3	30.0	35.3
12/17/2008	7.1	11.3	2.6	7.8	63.2	30.8	32.4
1/23/2009							
2/17/2009	5.9	8.2	2.0	6.0	65.9	27.0	38.9
3/24/2009	6.6	8.7	1.8	5.2	73.3	40.0	33.4
4/21/2009	6.8	10.1	1.5	6.0	77.5	41.1	36.3
5/28/2009	7.6	10.0	1.5	5.5	79.8	45.4	34.4
6/29/2009	7.3	9.2	2.4	5.8	67.6	37.1	30.5
7/21/2009	7.3	9.8	2.7	6.9	63.4	29.4	33.9
8/18/2009	7.7	9.2	2.8	7.2	64.0	21.4	42.6
9/15/2009	8.0	10.1	3.2	8.1	60.3	19.8	40.5
11/17/2009	7.6	9.1	2.8	7.5	62.6	17.8	44.9
12/15/2009	6.9	8.8	2.8	8.5	59.2	3.6	55.6
1/19/2010	6.8	7.4	2.1	6.3	69.5	14.8	54.7
2/18/2010	6.3	7.4	1.9	6.4	69.4	13.6	55.9
3/16/2010	5.5	7.3	1.8	6.5	67.5	11.5	56.0
4/22/2010	5.5	7.5	1.7	6.3	68.7	17.1	51.7
5/18/2010	5.9	8.4	1.9	7.1	68.3	15.3	53.0
Mean	6.2	10.2	1.7	4.8	72.0	47.6	25.3

Appendix E: Denitrification Enzyme Activity (DEA)

Introduction

All samples were assessed at the USDA-ARS laboratory in Grifton, Georgia according to the following methods:

Methods

1. Make up a 5000 ppm stock standard: Evacuate round flask three times, refill with air or N₂, withdraw 15 mL from flask, add 15 mL pure nitrous oxide. Mix by hand 1 min with beads swirling.
2. Make up 5, 10, 25, 50 ppm standards from stock standard. Evacuate flasks three times, refill with air or N₂, withdraw 3, 6, 15, 30 mL from the flasks. Add 3, 6, 15, and 30 mL of 5000ppm standard. One (1) PPM standard is in gas bottle.
3. If you need complete sets of higher standards (125 ppm, 250 ppm, etc) start with 10000 ppm stock by using 30 mL of pure nitrous oxide.
4. If you just need a few higher standards, you can make them up by carefully doing dilutions in the crimp top vials. Always use the glass syringe (marked standards only) to do these. All dilutions are based on (vol of standard or sample)/total volume of standard or sample plus diluent).
5. When making standards, be very careful not to leave the nitrous oxide tank on and let the gas escape into the room. This can contaminate the room air for a number of hours and make good standards difficult to obtain.
6. Fill vials with standards after checking one set to see if you have a good linear standardization.

Standardization of Gas Chromatograph

General: These GC standards tend to have a good bit of what seems like random variation. In general, we have used the means of all standards to calculate the line segments used for standardization. The lowest line segment goes through the origin.

1. Compile all standards for a run
2. Calculate mean area for each standard. Discard ones that are more than 10% different from the mean.

3. Determine line segments for calculation of unknowns. These are generally 0, air (0.3) 1, 5, 10 ppm then 10, 25 50 ppm, then 50, 125, 250 ppm, etc.
4. When you have the conc vs area relationships, calculate PPM of unknowns using line segments.

Gas sampling for nitrous oxide analysis

1. Generally, you will want to store mL samples in the crimp top vials. If you use a 5 mL sample, use 5 mL of standard. Make sure the sample volume and standard volume are the same.
2. For either cores or slurries, there will generally be two gas samples per incubation. The nitrous oxide production rate will be figured by the change in concentration over the time period between samples.
3. When taking samples from cores, pump the head space three times with the sampling syringe before sampling. Do not pull enough vacuum so that the core is sucked up into the top of the incubation syringe. Flush the syringe by pumping some room air between pumping the incubation syringes.

Core and slurry incubations

Cores

1. Before going to the field, number all incubation syringes and store in boxes in order that they will be taken. Core samples will come in from the field in the incubation syringe. Adjust the headspace on each one to 30 mL by either pushing the core up from the bottom or removing soil from the bottom and letting the core move down.
2. Place small red serum stopper firmly on tip of incubation syringe. Withdraw 3 mL from headspace, add mL acetylene. This should be done with the glass "acetylene only" syringe - three at a time can be done. Whenever you are injecting through these small serum stoppers, use a 23 G 1 inch needle.
3. Using 21 G 1 inch needle, pump each core three times with 50 mL syringe labeled pump. Be careful not to pull the core up so only pull about 10 mL.
4. Incubate for four hours, taking samples at 1 hour and four hours. Incubate at 25 C or room temp if incubator not available.

5. After incubation, measure the length (L) and headspace (HS) of each core and then store cores in freezer.

Slurries

1. Soils should be well mixed in the field, stored in whirlpak or ziplock bags with minimal headspace (squeeze air out). Store soil on ice from field and refrigerate in lab.

2. Before experiment starts, number and weigh all serum bottles you will use. Weigh bottles with grey serum stopper. Record weights on data sheets.

3. Place approximately 20 or 40 g of soil in the tared serum bottle. For soils expected to be high DEA, use 20g. For low DEA use 40 g. Either scoop soil into the bottle with a scoopula or use the 5 mL cutoff syringes (15mL = approx 20 g, 30mL = 40g). Get approximately 20 or 40 g in each bottle. Place grey serum stopper into serum bottle after soil is added to avoid drying.

4. Re-weigh bottle plus soil with serum stopper. Record weight on data sheets

5. Add 20 mL (or 40mL) of solution to each bottle from repipet. Slurries will be made with 20 mL (or 40 mL) of one or more of the following solutions:

a) solution 1 - 1 g/L chloramphenicol (chl)

b) solution 2 - 1 g/L chl and 200 mg NO₃-N/L (1.444 g KNO₃/L)

c) solution 3 - 1 g/L chl and 2 g glucose-C/L (5.505 g Glucose/L)

d) solution 4 - 1 g/L chl, 200 mg NO₃-N/L, 2 g Glucose-C/L - DEA

Solution 4 is used to measure actual denitrification potential or denitrifier enzyme assay.

6. Crimp top onto bottle. They are now ready to evacuate and gas.

7. Evacuate and gas in sets of twelve. Evacuate and add N₂ twice. Evacuate third time and add N₂/acetylene mixture. To take off bottles follow these steps: 1) turn three way valve back to the N₂ tank; 2) relieve overpressure by taking off bottle #1 leaving needle in the bottle; 3) take off other bottles; 4) turn valve to vacuum and turn vacuum off. **DO NOT TURN VACUUM OFF WHILE IT IS PULLING A VACUUM.**

8. Slurries should be incubated in the orbital shaker so that the slurry will remain well mixed. Incubate at room temp and record temp in your lab notebook.
9. Take samples at 1 hour and 4 hours after start of incubation. Record start and end times for a sampling in your lab notebook.
10. After gas sampling is done, weigh bottle, measure headspace in bottles by filling with water and re-weighing

Processing cores

When ready to process, allow to thaw, put entire core into weighed soil moisture can and then weigh entire core plus can. The core is now ready for subsampling for nitrate/ammonium extraction, gravimetric soil moisture determination, and any other measurements that will be done on the soil. Check with Dr. Mbuya to see what he wants you to do besides the KCl extract for nitrate/ammonium determination and the gravimetric soil moisture. This is how we would do these things: From the entire thawed core, weigh 12 grams of soil into bottle that can be placed on a shaker. Add 20 mL of a 2 M KCl solution and shake for one hour. Filter the solution into 20 mL scintillation vials and analyze the filtrate for nitrate and ammonium by standard colorimetric techniques. Take the remaining thawed soil and dry for three days at 105 C to a constant weight. Record the dry weight. This will allow calculation of gravimetric soil moisture. Please note, if total C or N needs to be determined on the soil, it needs to be done on an air-dried soil.

Processing bagged soils after they are used for slurries

Processing the bagged soils is similar to the cores except that the total weight of the bag of soil is not needed. After slurries are started, store bags in freezer. When ready to process, allow to thaw. From the thawed bag of soil, weigh 12 grams of soil into bottle that can be placed on a shaker. Add 20 mL of a 2 M KCl solution and shake for one hour. Filter the solution into 20mL scintillation vials and analyze the filtrate for nitrate and ammonium by standard colorimetric techniques. Take about 50 g (49-50 g) of the remaining thawed soil and dry for three days at 105 C to a constant weight. Record the dry weight. This will allow calculation of gravimetric soil moisture (SM) . Please note, if total C or N needs to be determined on the soil, it needs to be done on an air-dried soil.

Calculations for cores

Determine bulk density of cores based on the total mass of dried soil (including the portion removed for KCl extraction) and the volume of the core ($V = \pi * r^2 * L$). Bulk Density (BD) = mass (g)/volume (cubic centimeters). Total porosity (TP) is:

$$TP = (1 - (\text{bulk density} / \text{particle density}))$$

$$\% \text{Water Filled pore space} = [SM / (TP * V)] * 100$$

See Lowrance and Smittle (1988) paper for proper equations.

The denitrification calculations are shown here:

Need gravimetric soil moisture (SM), Headspace (HS); Total weight of core (TWC) incubation bottle.

$$\text{Time 2} - \text{Time 1} = \text{delta T (DT)}$$

$$\text{SoilWater} = SM * TWC$$

$$\text{SoilDry} = TWC - \text{SoilWater};$$

$$\text{Concentration Change (CC)} = N_2O(\text{Time2}) - N_2O(\text{Time1});$$

$$\text{Volume } N_2O = CC * HS + CC * \text{Soilwater} * 0.667 \quad \text{- this converts concentration to volume and accounts for dissolved } N_2O$$

$$\text{Mass } N_2O \text{ (ng)} = \text{Volume } N_2O * 1.842 \quad \text{- converts volume to mass.}$$

$$\text{Rate} = (\text{Mass } N_2O / \text{SoilDry}) * (24 / DT) \quad \text{- This converts to a daily rate. Can also express as hourly rate}$$

Calculations for denitrification potential

Determine fraction gravimetric soil moisture (SM);

Determine Headspace (HS) - usually = 130 ml for 20g samples and 100mL for 40g samples;

Record Soil Wet Weight (SoilWet) - the amount put into the incubation bottle.

$$\text{Time 2} - \text{Time 1} = \text{delta T (DT)}$$

$$\text{SoilWater} = \text{SM} * \text{SoilWet}$$

$$\text{TotalWater} = \text{SoilWater} + 20 \text{ (volume of solution added);}$$

$$\text{SoilDry} = \text{SoilWet} - \text{SoilWater};$$

$$\text{Concentration Change (CC)} = \text{N}_2\text{O}(\text{Time}_2) - \text{N}_2\text{O}(\text{Time}_1);$$

$$\text{Volume N}_2\text{O} = \text{CC} * \text{HS} + \text{CC} * \text{TotalWater} * 0.667 \text{ - this converts concentration to volume and accounts for dissolved N}_2\text{O}$$

$$\text{MassN}_2\text{O (ng)} = \text{Volume N}_2\text{O} * 1.842 \text{ - converts volume to mass.}$$

$$\text{Rate} = (\text{MassN}_2\text{O} / \text{SoilDry}) * (24 / \text{DT}) \text{ - This converts to a daily rate. Can also express as hourly rate}$$

Calculations for denitrification potential

Determine fraction gravimetric soil moisture (SM);

Determine Headspace (HS) - usually = 140 mL;

Record Soil Wet Weight (SoilWet) - the amount put into the incubation bottle.

Time 2 - Time 1 = delta T (DT)

$$\text{SoilWater} = \text{SM} * \text{SoilWet}$$

$$\text{TotalWater} = \text{SoilWater} + 20 \text{ (volume of solution added);}$$

$$\text{SoilDry} = \text{SoilWet} - \text{SoilWater};$$

$$\text{Concentration Change (CC)} = \text{N}_2\text{O}(\text{Time}_2) - \text{N}_2\text{O}(\text{Time}_1);$$

$$\text{Volume N}_2\text{O} = \text{CC} * \text{HS} + \text{CC} * \text{TotalWater} * 0.667 \text{ - this converts concentration to volume and accounts for dissolved N}_2\text{O}$$

$$\text{MassN}_2\text{O (ng)} = \text{Volume N}_2\text{O} * 1.842 \text{ - converts volume to mass.}$$

$$\text{Rate} = (\text{MassN}_2\text{O} / \text{SoilDry}) * (24 / \text{DT}) \text{ - This converts to a daily rate. Can also express as hourly rate}$$

Results

Block 1

Table 19 shows the denitrification enzyme activity rates for Block 1. All sample locations showed the potential for denitrification to occur. Rates showed a relatively small range between different depths and locations in Block 1 indicating that, depending on in-situ conditions, denitrification could plausibly occur. These values were much lower than the 576 $\mu\text{g N/kg dry soil/day}$ to 14,500 $\mu\text{g N/kg dry soil/day}$ range of DEA values measured in a wetland by Maitre et al (2005). However, the measurements still showed that denitrifying bacteria were present at different zones of the buffer and different depths.

Table 25. Block 1 denitrification enzyme activity rates

Location	Depth Below Ground Surface		
	30 cm	50 cm	80 cm
	<i>(Rates in $\mu\text{g N}_2\text{O-N/kg dry soil/day}$)</i>		
Pasture	28.6	40.0	33.2
Pasture Edge	33.4	61.4	63.0
Mid-Buffer	49.9	52.0	44.9
Stream Edge	67.6	35.6	47.0

Block 2

Table 20 shows the denitrification enzyme activity (DEA) rates for Block 2. DEA rates had a much larger range and were overall much higher than those found in Block 1. This seems to indicate that denitrification potential varied throughout the block but that it could plausibly occur under the proper in-situ conditions at any point in the buffer. Most of the measured values were much lower than the 576 $\mu\text{g N/kg dry soil/day}$ to 14,500 $\mu\text{g N/kg}$

dry soil/day range of DEA values measured in a wetland by Maitre et al (2005) except for the 30 cm depth at the stream edge.

Table 26. Block 2 denitrification enzyme activity rates

Location	Depth Below Ground Surface		
	30 cm	50 cm	80 cm
	<i>Rates in $\mu\text{g N}_2\text{O-N/Kg dry soil/day}$</i>		
Pasture	330.2	78.1	100.1
Pasture Edge	111.1	51.8	49.4
Mid-Buffer	76.8	54.7	54.7
Stream Edge	775.8	136.4	223.3

Block 3

Table 21 shows the denitrification enzyme activity rates for Block 3. All sample locations showed the potential for denitrification to occur. Most of the measured values were much lower than the 576 $\mu\text{g N/kg dry soil/day}$ to 14,500 $\mu\text{g N/kg dry soil/day}$ range of DEA values measured in a wetland by Maitre et al (2005). The 30 cm depth at the pasture edge and stream edge did fall within the range. However, the measurements still showed that denitrifying bacteria were present at different zones of the buffer and different depths and that, depending on in-situ conditions denitrification could plausibly occur.

Table 27. Block 3 Denitrification Enzyme Activity values.

Location	Depth Below Ground Surface		
	30 cm	50 cm	80 cm
	<i>Rates in $\mu\text{g N}_2\text{O-N/Kg dry soil/day}$</i>		
Pasture	104.62	62.79	120.14
Pasture Edge	862.83	83.07	64.08
Mid-Buffer	328.44	206.38	121.86
Stream Edge	1670.35	184.04	101.91

Appendix F: Statistical Analysis

Example Code for individual Block analysis

The following code was used to find significant differences in groundwater samples between well positions at different depths.

```
options ls=85 nodate nocenter formdlm="+";

data one;
  infile "CREP_Stats.csv"
  firstobs=4 dlm="," dsd;
  input SampleID $ Date : mmddyy10. Block Transect $ WellPosition Depth $
  NO3 Cl NCl DOC lnNO3 lnCl lnNCl lnDOC;
  week=week(date);
  run;
  data sorttime;
set one;
run;
proc sort data=sorttime;
by block SampleID Date;
run;

proc mixed data=sorttime COVTEST;
  by block;
  class SampleID depth wellposition transect week block date ;
  model lnno3=wellposition|depth / outp=two;
  *model no3=wellposition depth wellposition*depth;
  random transect transect*wellposition week;
  *random treatment transect(treatment) transect*wellposition(treatment);
  *repeated /subject=transect*wellposition*treatment type=ar(1);
  *repeated /subject=transect*wellposition type=ar(1);
  repeated/subject=SampleID type=ar(1);
  *lsmeans wellposition/cl diff;
  lsmeans wellposition|depth/slice=(wellposition depth) cl diff;
run;
```

SAS Output for NO3-N Concentration Analysis

```
+++++
The SAS System 92

Block=.

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
Dependent Variable lnNO3
```

+++++

The SAS System

93

Block=1

The Mixed Procedure

Model Information

Data Set	WORK.SORTTIME
Dependent Variable	lnNO3
Covariance Structures	Variance Components, Autoregressive
Subject Effect	SampleID
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
SampleID	15	Jav1-a1d Jav1-a1s Jav1-a2s Jav1-a3s Jav1-b1d Jav1-b1s Jav1-b2s Jav1-b3d Jav1-b3s Jav1-c1d Jav1-c1s Jav1-c2d Jav1-c2s Jav1-c3d Jav1-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51
Block	1	1
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644 16658 16671 16708 16736 16771 16813 16841 16869 16904 16933 16960 17023 17064 17092 17126 17155 17190 17218 17246 17257 17287 17318 17348 17398 17426 17463 17494 17617 17644 17665 17693 17721 17750 17799 17827 17855 17883 17920 17945 17980 18008 18045 18077 18099 18127 18155 18190 18218 18246 18281 18311 18337 18374 18400

+++++

The SAS System

94

Block=1

The Mixed Procedure

Dimensions

Covariance Parameters	5
Columns in X	12
Columns in Z	52
Subjects	1
Max Obs Per Subject	884

Number of Observations

Number of Observations Read	884
Number of Observations Used	884
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	3175.44945978	

WARNING: Stopped because of infinite likelihood.

Covariance Parameter Values At Last Iteration

Cov Parm	Subject	Estimate
Transect		0.1238
WellPositio*Transect		2.1955
week		0.01647
AR(1)	SampleID	0.2669
Residual		0.7227

+++++

The SAS System 95

Block=2

The Mixed Procedure

Model Information

Data Set	WORK.SORTTIME
Dependent Variable	lnNO3
Covariance Structures	Variance Components, Autoregressive
Subject Effect	SampleID
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
SampleID	18	Jav2-a1d Jav2-a1s Jav2-a2d Jav2-a2s Jav2-a3d Jav2-a3s Jav2-b1d Jav2-b1s Jav2-b2d Jav2-b2s Jav2-b3d Jav2-b3s

		Jav2-c1d	Jav2-c1s	Jav2-c2d																
		Jav2-c2s	Jav2-c3d	Jav2-c3s																
Depth	2	D	S																	
WellPosition	3	1	2	3																
Transect	3	A	B	C																
week	40	2	3	4	6	7	8	10	11	12	13	14	15							
		16	17	18	19	20	21	22	23	24	26									
		27	28	29	30	31	32	33	34	37	38									
		39	42	43	46	47	48	50	51											
Block	1	2																		
Date	69	16448	16462	16476	16490	16505														
		16518	16532	16546	16561	16574														
		16589	16602	16616	16630	16644														
		16658	16671	16708	16736	16771														
		16813	16841	16869	16904	16933														
		16960	17023	17064	17092	17126														
		17155	17190	17218	17246	17257														
		17287	17318	17348	17398	17426														
		17463	17494	17617	17644	17665														
		17693	17721	17750	17799	17827														
		17855	17883	17920	17945	17980														
		18008	18045	18077	18099	18127														
		18155	18190	18218	18246	18281														
		18311	18337	18374	18400															

+++++

The SAS System 96

Block=2

The Mixed Procedure

Dimensions

Covariance Parameters	5
Columns in X	12
Columns in Z	52
Subjects	1
Max Obs Per Subject	1111

Number of Observations

Number of Observations Read	1111
Number of Observations Used	1111
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	4045.78963388	
1	3	2643.86557680	0.00093310
2	1	2643.53946409	0.00006070
3	1	2643.52001412	0.00000032
4	1	2643.51991467	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		1.8028	1.8306	0.98	0.1624
WellPositio*Transect		0.04727	0.05977	0.79	0.2145
week		0.01495	0.007615	1.96	0.0248
AR(1)	SampleID	0.6399	0.02481	25.79	<.0001
Residual		1.0211	0.07050	14.48	<.0001

Fit Statistics

-2 Res Log Likelihood	2643.5
AIC (smaller is better)	2653.5
AICC (smaller is better)	2653.6
BIC (smaller is better)	2649.0

+++++

The SAS System 97

Block=2

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	37.91	0.0025
Depth	1	1060	3.62	0.0574
Depth*WellPosition	2	1060	0.39	0.6790

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	1.3860	0.7940	4	1.75	0.1558
WellPosition		2	-0.6257	0.7933	4	-0.79	0.4744
WellPosition		3	-0.08165	0.7926	4	-0.10	0.9229
Depth	D		0.3457	0.7834	1060	0.44	0.6591
Depth	S		0.1068	0.7846	1060	0.14	0.8918
Depth*WellPosition	D	1	1.4456	0.7990	1060	1.81	0.0707
Depth*WellPosition	D	2	-0.4325	0.7984	1060	-0.54	0.5881
Depth*WellPosition	D	3	0.02389	0.7992	1060	0.03	0.9762
Depth*WellPosition	S	1	1.3264	0.8054	1060	1.65	0.0999
Depth*WellPosition	S	2	-0.8189	0.8022	1060	-1.02	0.3076
Depth*WellPosition	S	3	-0.1872	0.8000	1060	-0.23	0.8150

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	-0.8184	3.5903
WellPosition		2	0.05	-2.8283	1.5770
WellPosition		3	0.05	-2.2823	2.1190
Depth	D		0.05	-1.1914	1.8828

Depth	S		0.05	-1.4328	1.6463
Depth*WellPosition	D	1	0.05	-0.1223	3.0135
Depth*WellPosition	D	2	0.05	-1.9992	1.1342
Depth*WellPosition	D	3	0.05	-1.5443	1.5920
Depth*WellPosition	S	1	0.05	-0.2541	2.9068
Depth*WellPosition	S	2	0.05	-2.3929	0.7552
Depth*WellPosition	S	3	0.05	-1.7569	1.3825

+++++

The SAS System 98

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
WellPosition		1		2	2.0117	0.2387	4
WellPosition		1		3	1.4676	0.2363	4
WellPosition		2		3	-0.5440	0.2343	4
Depth	D		S		0.2389	0.1256	1060
Depth*WellPosition	D	1	D	2	1.8781	0.2707	1060
Depth*WellPosition	D	1	D	3	1.4217	0.2729	1060
Depth*WellPosition	D	1	S	1	0.1192	0.2301	1060
Depth*WellPosition	D	1	S	2	2.2645	0.2815	1060
Depth*WellPosition	D	1	S	3	1.6328	0.2752	1060
Depth*WellPosition	D	2	D	3	-0.4564	0.2711	1060
Depth*WellPosition	D	2	S	1	-1.7589	0.2889	1060
Depth*WellPosition	D	2	S	2	0.3864	0.2109	1060
Depth*WellPosition	D	2	S	3	-0.2453	0.2734	1060
Depth*WellPosition	D	3	S	1	-1.3025	0.2909	1060
Depth*WellPosition	D	3	S	2	0.8428	0.2819	1060
Depth*WellPosition	D	3	S	3	0.2111	0.2107	1060
Depth*WellPosition	S	1	S	2	2.1452	0.2990	1060
Depth*WellPosition	S	1	S	3	1.5135	0.2931	1060
Depth*WellPosition	S	2	S	3	-0.6317	0.2841	1060

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	8.43	0.0011	0.05
WellPosition		1		3	6.21	0.0034	0.05
WellPosition		2		3	-2.32	0.0809	0.05
Depth	D		S		1.90	0.0574	0.05
Depth*WellPosition	D	1	D	2	6.94	<.0001	0.05
Depth*WellPosition	D	1	D	3	5.21	<.0001	0.05
Depth*WellPosition	D	1	S	1	0.52	0.6044	0.05
Depth*WellPosition	D	1	S	2	8.04	<.0001	0.05
Depth*WellPosition	D	1	S	3	5.93	<.0001	0.05
Depth*WellPosition	D	2	D	3	-1.68	0.0926	0.05
Depth*WellPosition	D	2	S	1	-6.09	<.0001	0.05
Depth*WellPosition	D	2	S	2	1.83	0.0672	0.05
Depth*WellPosition	D	2	S	3	-0.90	0.3698	0.05
Depth*WellPosition	D	3	S	1	-4.48	<.0001	0.05
Depth*WellPosition	D	3	S	2	2.99	0.0029	0.05

Depth*WellPosition	D	3	S	3	1.00	0.3168	0.05
Depth*WellPosition	S	1	S	2	7.18	<.0001	0.05
Depth*WellPosition	S	1	S	3	5.16	<.0001	0.05

+++++

The SAS System 99

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	-2.22	0.0264	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
WellPosition		1		2	1.3488	2.6745
WellPosition		1		3	0.8115	2.1237
WellPosition		2		3	-1.1945	0.1064
Depth	D		S		-0.00754	0.4853
Depth*WellPosition	D	1	D	2	1.3469	2.4092
Depth*WellPosition	D	1	D	3	0.8863	1.9571
Depth*WellPosition	D	1	S	1	-0.3322	0.5707
Depth*WellPosition	D	1	S	2	1.7121	2.8168
Depth*WellPosition	D	1	S	3	1.0928	2.1727
Depth*WellPosition	D	2	D	3	-0.9883	0.07552
Depth*WellPosition	D	2	S	1	-2.3258	-1.1919
Depth*WellPosition	D	2	S	2	-0.02744	0.8002
Depth*WellPosition	D	2	S	3	-0.7818	0.2912
Depth*WellPosition	D	3	S	1	-1.8734	-0.7316
Depth*WellPosition	D	3	S	2	0.2896	1.3959
Depth*WellPosition	D	3	S	3	-0.2024	0.6246
Depth*WellPosition	S	1	S	2	1.5586	2.7319
Depth*WellPosition	S	1	S	3	0.9384	2.0886
Depth*WellPosition	S	2	S	3	-1.1891	-0.07430

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	1060	0.27	0.6044
Depth*WellPosition		2	1	1060	3.36	0.0672
Depth*WellPosition		3	1	1060	1.00	0.3168
Depth*WellPosition	D		2	1060	26.05	<.0001
Depth*WellPosition	S		2	1060	26.92	<.0001

+++++

The SAS System 100

Block=3

The Mixed Procedure

Model Information

```
Data Set                WORK.SORTTIME
Dependent Variable      lnNO3
Covariance Structures  Variance Components,
                        Autoregressive
Subject Effect          SampleID
Estimation Method       REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment
```

Class Level Information

```
Class      Levels  Values
SampleID   18      Jav3-a1d Jav3-a1s Jav3-a2d
                        Jav3-a2s Jav3-a3d Jav3-a3s
                        Jav3-b1d Jav3-b1s Jav3-b2d
                        Jav3-b2s Jav3-b3d Jav3-b3s
                        Jav3-c1d Jav3-c1s Jav3-c2d
                        Jav3-c2s Jav3-c3d Jav3-c3s
Depth      2        D S
WellPosition 3        1 2 3
Transect    3        A B C
week        40      2 3 4 6 7 8 10 11 12 13 14 15
                        16 17 18 19 20 21 22 23 24 26
                        27 28 29 30 31 32 33 34 37 38
                        39 42 43 46 47 48 50 51
Block      1        3
Date       69      16448 16462 16476 16490 16505
                        16518 16532 16546 16561 16574
                        16589 16602 16616 16630 16644
                        16658 16671 16708 16736 16771
                        16813 16841 16869 16904 16933
                        16960 17023 17064 17092 17126
                        17155 17190 17218 17246 17257
                        17287 17318 17348 17398 17426
                        17463 17494 17617 17644 17665
                        17693 17721 17750 17799 17827
                        17855 17883 17920 17945 17980
                        18008 18045 18077 18099 18127
                        18155 18190 18218 18246 18281
                        18311 18337 18374 18400
```

+++++

The SAS System 101

Block=3

The Mixed Procedure

Dimensions

```
Covariance Parameters      5
Columns in X                12
Columns in Z                52
Subjects                    1
Max Obs Per Subject        1044
```

Number of Observations

Number of Observations Read	1044
Number of Observations Used	1042
Number of Observations Not Used	2

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	3107.42662468	
1	3	2408.84292982	0.00045910
2	1	2408.71928087	0.00000800
3	1	2408.71723061	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0	.	.	.
WellPositio*Transect		0.1551	0.1156	1.34	0.0898
week		0.01187	0.006193	1.92	0.0277
AR(1)	SampleID	0.6819	0.02429	28.07	<.0001
Residual		1.0568	0.08063	13.11	<.0001

Fit Statistics

-2 Res Log Likelihood	2408.7
AIC (smaller is better)	2416.7
AICC (smaller is better)	2416.8
BIC (smaller is better)	2413.1

+++++

The SAS System 102

Block=3

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	11.88	0.0208
Depth	1	991	49.56	<.0001
Depth*WellPosition	2	991	3.93	0.0199

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
--------	-------	---------------	----------	----------------	----	---------	---------

WellPosition		1	1.3506	0.2630	4	5.14	0.0068
WellPosition		2	-0.1028	0.2587	4	-0.40	0.7113
WellPosition		3	-0.2901	0.2577	4	-1.13	0.3231
Depth	D		0.8244	0.1622	991	5.08	<.0001
Depth	S		-0.1860	0.1717	991	-1.08	0.2791
Depth*WellPosition	D	1	1.5924	0.2822	991	5.64	<.0001
Depth*WellPosition	D	2	0.6392	0.2784	991	2.30	0.0219
Depth*WellPosition	D	3	0.2417	0.2784	991	0.87	0.3854
Depth*WellPosition	S	1	1.1089	0.3048	991	3.64	0.0003
Depth*WellPosition	S	2	-0.8448	0.2933	991	-2.88	0.0041
Depth*WellPosition	S	3	-0.8220	0.2897	991	-2.84	0.0046

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	0.6205	2.0808
WellPosition		2	0.05	-0.8210	0.6154
WellPosition		3	0.05	-1.0055	0.4253
Depth	D		0.05	0.5062	1.1427
Depth	S		0.05	-0.5229	0.1510
Depth*WellPosition	D	1	0.05	1.0386	2.1462
Depth*WellPosition	D	2	0.05	0.09293	1.1854
Depth*WellPosition	D	3	0.05	-0.3045	0.7879
Depth*WellPosition	S	1	0.05	0.5109	1.7069
Depth*WellPosition	S	2	0.05	-1.4204	-0.2692
Depth*WellPosition	S	3	0.05	-1.3906	-0.2534

+++++

The SAS System

103

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
WellPosition		1		2	1.4535	0.3679	4
WellPosition		1		3	1.6408	0.3672	4
WellPosition		2		3	0.1873	0.3641	4
Depth	D		S		1.0104	0.1435	991
Depth*WellPosition	D	1	D	2	0.9532	0.3955	991
Depth*WellPosition	D	1	D	3	1.3507	0.3955	991
Depth*WellPosition	D	1	S	1	0.4835	0.2616	991
Depth*WellPosition	D	1	S	2	2.4372	0.4061	991
Depth*WellPosition	D	1	S	3	2.4144	0.4036	991
Depth*WellPosition	D	2	D	3	0.3975	0.3928	991
Depth*WellPosition	D	2	S	1	-0.4697	0.4119	991
Depth*WellPosition	D	2	S	2	1.4840	0.2437	991
Depth*WellPosition	D	2	S	3	1.4612	0.4009	991
Depth*WellPosition	D	3	S	1	-0.8672	0.4119	991
Depth*WellPosition	D	3	S	2	1.0865	0.4035	991
Depth*WellPosition	D	3	S	3	1.0637	0.2394	991
Depth*WellPosition	S	1	S	2	1.9537	0.4219	991
Depth*WellPosition	S	1	S	3	1.9309	0.4195	991
Depth*WellPosition	S	2	S	3	-0.02284	0.4113	991

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	3.95	0.0168	0.05
WellPosition		1		3	4.47	0.0111	0.05
WellPosition		2		3	0.51	0.6341	0.05
Depth	D		S		7.04	<.0001	0.05
Depth*WellPosition	D	1	D	2	2.41	0.0161	0.05
Depth*WellPosition	D	1	D	3	3.41	0.0007	0.05
Depth*WellPosition	D	1	S	1	1.85	0.0648	0.05
Depth*WellPosition	D	1	S	2	6.00	<.0001	0.05
Depth*WellPosition	D	1	S	3	5.98	<.0001	0.05
Depth*WellPosition	D	2	D	3	1.01	0.3118	0.05
Depth*WellPosition	D	2	S	1	-1.14	0.2544	0.05
Depth*WellPosition	D	2	S	2	6.09	<.0001	0.05
Depth*WellPosition	D	2	S	3	3.64	0.0003	0.05
Depth*WellPosition	D	3	S	1	-2.11	0.0355	0.05
Depth*WellPosition	D	3	S	2	2.69	0.0072	0.05
Depth*WellPosition	D	3	S	3	4.44	<.0001	0.05
Depth*WellPosition	S	1	S	2	4.63	<.0001	0.05
Depth*WellPosition	S	1	S	3	4.60	<.0001	0.05

+++++

The SAS System

104

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	-0.06	0.9557	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
WellPosition		1		2	0.4321	2.4748
WellPosition		1		3	0.6214	2.6602
WellPosition		2		3	-0.8236	1.1983
Depth	D		S		0.7288	1.2920
Depth*WellPosition	D	1	D	2	0.1770	1.7294
Depth*WellPosition	D	1	D	3	0.5745	2.1269
Depth*WellPosition	D	1	S	1	-0.02980	0.9968
Depth*WellPosition	D	1	S	2	1.6402	3.2342
Depth*WellPosition	D	1	S	3	1.6224	3.2064
Depth*WellPosition	D	2	D	3	-0.3733	1.1682
Depth*WellPosition	D	2	S	1	-1.2780	0.3385
Depth*WellPosition	D	2	S	2	1.0058	1.9622
Depth*WellPosition	D	2	S	3	0.6744	2.2479
Depth*WellPosition	D	3	S	1	-1.6754	-0.05897
Depth*WellPosition	D	3	S	2	0.2947	1.8783
Depth*WellPosition	D	3	S	3	0.5939	1.5334
Depth*WellPosition	S	1	S	2	1.1257	2.7817
Depth*WellPosition	S	1	S	3	1.1077	2.7541

Depth*WellPosition S 2 S 3 -0.8300 0.7843

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	991	3.42	0.0648
Depth*WellPosition		2	1	991	37.09	<.0001
Depth*WellPosition		3	1	991	19.75	<.0001
Depth*WellPosition	D		2	991	6.14	0.0022
Depth*WellPosition	S		2	991	14.00	<.0001

SAS Output for Cl- Concentration Analysis

+++++

The SAS System 122

Block=.

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnCl

+++++

The SAS System 123

Block=1

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnCl
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	15	Jav1-a1d Jav1-a1s Jav1-a2s Jav1-a3s Jav1-b1d Jav1-b1s Jav1-b2s Jav1-b3d Jav1-b3s Jav1-c1d Jav1-c1s Jav1-c2d Jav1-c2s Jav1-c3d Jav1-c3s

```

Depth          2      D S
WellPosition   3      1 2 3
Transect       3      A B C
week           40     2 3 4 6 7 8 10 11 12 13 14 15
                16 17 18 19 20 21 22 23 24 26
                27 28 29 30 31 32 33 34 37 38
                39 42 43 46 47 48 50 51

Block          1      1
Date           69     16448 16462 16476 16490 16505
                16518 16532 16546 16561 16574
                16589 16602 16616 16630 16644
                16658 16671 16708 16736 16771
                16813 16841 16869 16904 16933
                16960 17023 17064 17092 17126
                17155 17190 17218 17246 17257
                17287 17318 17348 17398 17426
                17463 17494 17617 17644 17665
                17693 17721 17750 17799 17827
                17855 17883 17920 17945 17980
                18008 18045 18077 18099 18127
                18155 18190 18218 18246 18281
                18311 18337 18374 18400

```

+++++

The SAS System 124

Block=1

The Mixed Procedure

Dimensions

```

Covariance Parameters      5
Columns in X                12
Columns in Z                52
Subjects                    1
Max Obs Per Subject        884

```

Number of Observations

```

Number of Observations Read      884
Number of Observations Used      795
Number of Observations Not Used   89

```

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	1539.63367824	
1	3	1237.52824231	0.00766771
2	1	1236.64113229	0.00037712
3	1	1236.59851666	0.00000342
4	1	1236.59814924	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0	.	.	.
WellPositio*Transect		0.05288	0.03711	1.43	0.0771
week		0.05412	0.01679	3.22	0.0006
AR(1)	SampleID	0.4855	0.03529	13.76	<.0001
Residual		0.3236	0.02236	14.47	<.0001

Fit Statistics

-2 Res Log Likelihood	1236.6
AIC (smaller is better)	1244.6
AICC (smaller is better)	1244.6
BIC (smaller is better)	1241.0

+++++

The SAS System 125

Block=1

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	12.07	0.0202
Depth	1	746	1.59	0.2084
Depth*WellPosition	2	746	9.34	<.0001

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	2.1458	0.1526	4	14.06	0.0001
WellPosition		2	2.2501	0.1620	4	13.89	0.0002
WellPosition		3	1.3084	0.1509	4	8.67	0.0010
Depth	D		1.9519	0.1071	746	18.22	<.0001
Depth	S		1.8509	0.09920	746	18.66	<.0001
Depth*WellPosition	D	1	2.3571	0.1554	746	15.16	<.0001
Depth*WellPosition	D	2	2.3480	0.2043	746	11.49	<.0001
Depth*WellPosition	D	3	1.1507	0.1684	746	6.83	<.0001
Depth*WellPosition	S	1	1.9345	0.1750	746	11.05	<.0001
Depth*WellPosition	S	2	2.1523	0.1563	746	13.77	<.0001
Depth*WellPosition	S	3	1.4660	0.1557	746	9.41	<.0001

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	1.7220	2.5696
WellPosition		2	0.05	1.8004	2.6999
WellPosition		3	0.05	0.8893	1.7274
Depth	D		0.05	1.7417	2.1622
Depth	S		0.05	1.6562	2.0457
Depth*WellPosition	D	1	0.05	2.0520	2.6623

Depth*WellPosition	D	2	0.05	1.9470	2.7490
Depth*WellPosition	D	3	0.05	0.8201	1.4813
Depth*WellPosition	S	1	0.05	1.5909	2.2781
Depth*WellPosition	S	2	0.05	1.8454	2.4592
Depth*WellPosition	S	3	0.05	1.1603	1.7717

+++++

The SAS System

126

Block=1

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
WellPosition		1		2	-0.1043	0.2156	4
WellPosition		1		3	0.8374	0.2075	4
WellPosition		2		3	0.9418	0.2145	4
Depth	D		S		0.1010	0.08020	746
Depth*WellPosition	D	1	D	2	0.009125	0.2508	746
Depth*WellPosition	D	1	D	3	1.2064	0.2226	746
Depth*WellPosition	D	1	S	1	0.4226	0.1281	746
Depth*WellPosition	D	1	S	2	0.2048	0.2135	746
Depth*WellPosition	D	1	S	3	0.8911	0.2131	746
Depth*WellPosition	D	2	D	3	1.1973	0.2590	746
Depth*WellPosition	D	2	S	1	0.4135	0.2631	746
Depth*WellPosition	D	2	S	2	0.1957	0.1654	746
Depth*WellPosition	D	2	S	3	0.8819	0.2510	746
Depth*WellPosition	D	3	S	1	-0.7838	0.2365	746
Depth*WellPosition	D	3	S	2	-1.0016	0.2232	746
Depth*WellPosition	D	3	S	3	-0.3153	0.1187	746
Depth*WellPosition	S	1	S	2	-0.2178	0.2279	746
Depth*WellPosition	S	1	S	3	0.4685	0.2276	746
Depth*WellPosition	S	2	S	3	0.6862	0.2138	746

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	-0.48	0.6537	0.05
WellPosition		1		3	4.04	0.0156	0.05
WellPosition		2		3	4.39	0.0118	0.05
Depth	D		S		1.26	0.2084	0.05
Depth*WellPosition	D	1	D	2	0.04	0.9710	0.05
Depth*WellPosition	D	1	D	3	5.42	<.0001	0.05
Depth*WellPosition	D	1	S	1	3.30	0.0010	0.05
Depth*WellPosition	D	1	S	2	0.96	0.3378	0.05
Depth*WellPosition	D	1	S	3	4.18	<.0001	0.05
Depth*WellPosition	D	2	D	3	4.62	<.0001	0.05
Depth*WellPosition	D	2	S	1	1.57	0.1165	0.05
Depth*WellPosition	D	2	S	2	1.18	0.2371	0.05
Depth*WellPosition	D	2	S	3	3.51	0.0005	0.05
Depth*WellPosition	D	3	S	1	-3.31	0.0010	0.05
Depth*WellPosition	D	3	S	2	-4.49	<.0001	0.05
Depth*WellPosition	D	3	S	3	-2.66	0.0081	0.05
Depth*WellPosition	S	1	S	2	-0.96	0.3396	0.05

Depth*WellPosition S 1 S 3 2.06 0.0399 0.05

+++++

The SAS System 127

Block=1

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	3.21	0.0014	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
WellPosition		1		2	-0.7028	0.4942
WellPosition		1		3	0.2614	1.4134
WellPosition		2		3	0.3461	1.5374
Depth	D		S		-0.05646	0.2584
Depth*WellPosition	D	1	D	2	-0.4832	0.5014
Depth*WellPosition	D	1	D	3	0.7695	1.6433
Depth*WellPosition	D	1	S	1	0.1711	0.6741
Depth*WellPosition	D	1	S	2	-0.2144	0.6240
Depth*WellPosition	D	1	S	3	0.4727	1.3095
Depth*WellPosition	D	2	D	3	0.6888	1.7058
Depth*WellPosition	D	2	S	1	-0.1031	0.9300
Depth*WellPosition	D	2	S	2	-0.1290	0.5204
Depth*WellPosition	D	2	S	3	0.3893	1.3746
Depth*WellPosition	D	3	S	1	-1.2480	-0.3196
Depth*WellPosition	D	3	S	2	-1.4397	-0.5635
Depth*WellPosition	D	3	S	3	-0.5484	-0.08224
Depth*WellPosition	S	1	S	2	-0.6652	0.2296
Depth*WellPosition	S	1	S	3	0.02168	0.9152
Depth*WellPosition	S	2	S	3	0.2666	1.1059

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	746	10.88	0.0010
Depth*WellPosition		2	1	746	1.40	0.2371
Depth*WellPosition		3	1	746	7.05	0.0081
Depth*WellPosition	D		2	746	17.50	<.0001
Depth*WellPosition	S		2	746	5.35	0.0049

+++++

The SAS System 128

Block=2

The Mixed Procedure

Model Information

```

Data Set                WORK.SORTTIME
Dependent Variable      lnCl
Covariance Structures  Variance Components,
                        Autoregressive
Subject Effect          SampleID
Estimation Method       REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

```

Class Level Information

```

Class      Levels  Values
SampleID   18      Jav2-a1d Jav2-a1s Jav2-a2d
                        Jav2-a2s Jav2-a3d Jav2-a3s
                        Jav2-b1d Jav2-b1s Jav2-b2d
                        Jav2-b2s Jav2-b3d Jav2-b3s
                        Jav2-c1d Jav2-c1s Jav2-c2d
                        Jav2-c2s Jav2-c3d Jav2-c3s
Depth      2        D S
WellPosition 3      1 2 3
Transect    3      A B C
week        40      2 3 4 6 7 8 10 11 12 13 14 15
                        16 17 18 19 20 21 22 23 24 26
                        27 28 29 30 31 32 33 34 37 38
                        39 42 43 46 47 48 50 51
Block      1        2
Date       69      16448 16462 16476 16490 16505
                        16518 16532 16546 16561 16574
                        16589 16602 16616 16630 16644
                        16658 16671 16708 16736 16771
                        16813 16841 16869 16904 16933
                        16960 17023 17064 17092 17126
                        17155 17190 17218 17246 17257
                        17287 17318 17348 17398 17426
                        17463 17494 17617 17644 17665
                        17693 17721 17750 17799 17827
                        17855 17883 17920 17945 17980
                        18008 18045 18077 18099 18127
                        18155 18190 18218 18246 18281
                        18311 18337 18374 18400

```

+++++

The SAS System 129

Block=2

The Mixed Procedure

Dimensions

```

Covariance Parameters      5
Columns in X               12
Columns in Z               52
Subjects                   1
Max Obs Per Subject       1111

```

Number of Observations

Number of Observations Read 1111
 Number of Observations Used 1016
 Number of Observations Not Used 95

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	2146.10894062	
1	3	1657.04896010	0.03803671
2	2	1655.57519035	0.00587281
3	1	1654.90020982	0.00046762
4	1	1654.85027080	0.00000453
5	1	1654.84981135	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0	.	.	.
WellPositio*Transect		0.01089	0.01701	0.64	0.2610
week		0.06316	0.01849	3.42	0.0003
AR(1)	SampleID	0.6481	0.02968	21.84	<.0001
Residual		0.4644	0.03660	12.69	<.0001

Fit Statistics

-2 Res Log Likelihood 1654.8
 AIC (smaller is better) 1662.8
 AICC (smaller is better) 1662.9

+++++

The SAS System 130

Block=2

The Mixed Procedure

Fit Statistics

BIC (smaller is better) 1659.2

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	27.68	0.0045
Depth	1	967	8.47	0.0037
Depth*WellPosition	2	967	4.48	0.0115

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	2.0829	0.1103	4	18.89	<.0001
WellPosition		2	1.3647	0.1072	4	12.73	0.0002
WellPosition		3	1.0632	0.1044	4	10.19	0.0005
Depth	D		1.3742	0.08025	967	17.12	<.0001
Depth	S		1.6330	0.08683	967	18.81	<.0001
Depth*WellPosition	D	1	2.1442	0.1266	967	16.93	<.0001
Depth*WellPosition	D	2	1.1093	0.1242	967	8.93	<.0001
Depth*WellPosition	D	3	0.8690	0.1269	967	6.85	<.0001
Depth*WellPosition	S	1	2.0216	0.1477	967	13.69	<.0001
Depth*WellPosition	S	2	1.6201	0.1362	967	11.89	<.0001

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	1.7768	2.3891
WellPosition		2	0.05	1.0670	1.6624
WellPosition		3	0.05	0.7734	1.3530
Depth	D		0.05	1.2167	1.5316
Depth	S		0.05	1.4626	1.8034
Depth*WellPosition	D	1	0.05	1.8957	2.3927
Depth*WellPosition	D	2	0.05	0.8656	1.3529
Depth*WellPosition	D	3	0.05	0.6200	1.1180
Depth*WellPosition	S	1	0.05	1.7318	2.3114
Depth*WellPosition	S	2	0.05	1.3528	1.8875

+++++

The SAS System 131

Block=2

The Mixed Procedure

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
Depth*WellPosition	S	3	1.2574	0.1294	967	9.72	<.0001

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
Depth*WellPosition	S	3	0.05	1.0035	1.5112

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Estimate	Standard Error	DF
WellPosition		1		2	0.7182	0.1419	4
WellPosition		1		3	1.0197	0.1398	4
WellPosition		2		3	0.3015	0.1375	4
Depth	D		S		-0.2589	0.08897	967

Depth*WellPosition D 1 D 2 1.0350 0.1673 967

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	5.06	0.0072	0.05
WellPosition		1		3	7.30	0.0019	0.05
WellPosition		2		3	2.19	0.0934	0.05
Depth	D		S		-2.91	0.0037	0.05
Depth*WellPosition	D	1	D	2	6.19	<.0001	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
WellPosition		1		2	0.3244	1.1121
WellPosition		1		3	0.6317	1.4078
WellPosition		2		3	-0.08019	0.6832
Depth	D		S		-0.4335	-0.08430
Depth*WellPosition	D	1	D	2	0.7067	1.3632

+++++

The SAS System

132

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
Depth*WellPosition	D	1	D	3	1.2752	0.1693	967
Depth*WellPosition	D	1	S	1	0.1226	0.1645	967
Depth*WellPosition	D	1	S	2	0.5241	0.1764	967
Depth*WellPosition	D	1	S	3	0.8869	0.1711	967
Depth*WellPosition	D	2	D	3	0.2403	0.1674	967
Depth*WellPosition	D	2	S	1	-0.9124	0.1835	967
Depth*WellPosition	D	2	S	2	-0.5109	0.1482	967
Depth*WellPosition	D	2	S	3	-0.1481	0.1693	967
Depth*WellPosition	D	3	S	1	-1.1526	0.1854	967
Depth*WellPosition	D	3	S	2	-0.7512	0.1765	967
Depth*WellPosition	D	3	S	3	-0.3884	0.1486	967
Depth*WellPosition	S	1	S	2	0.4015	0.1916	967
Depth*WellPosition	S	1	S	3	0.7642	0.1869	967
Depth*WellPosition	S	2	S	3	0.3628	0.1783	967

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	D	1	D	3	7.53	<.0001	0.05
Depth*WellPosition	D	1	S	1	0.75	0.4561	0.05
Depth*WellPosition	D	1	S	2	2.97	0.0030	0.05
Depth*WellPosition	D	1	S	3	5.18	<.0001	0.05
Depth*WellPosition	D	2	D	3	1.43	0.1516	0.05
Depth*WellPosition	D	2	S	1	-4.97	<.0001	0.05

Depth*WellPosition	D	2	S	2	-3.45	0.0006	0.05
Depth*WellPosition	D	2	S	3	-0.87	0.3819	0.05
Depth*WellPosition	D	3	S	1	-6.22	<.0001	0.05
Depth*WellPosition	D	3	S	2	-4.26	<.0001	0.05
Depth*WellPosition	D	3	S	3	-2.61	0.0091	0.05
Depth*WellPosition	S	1	S	2	2.09	0.0364	0.05
Depth*WellPosition	S	1	S	3	4.09	<.0001	0.05
Depth*WellPosition	S	2	S	3	2.03	0.0421	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
Depth*WellPosition	D	1	D	3	0.9430	1.6075
Depth*WellPosition	D	1	S	1	-0.2001	0.4454
Depth*WellPosition	D	1	S	2	0.1780	0.8702

+++++

The SAS System 133

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
Depth*WellPosition	D	1	S	3	0.5510	1.2227
Depth*WellPosition	D	2	D	3	-0.08831	0.5689
Depth*WellPosition	D	2	S	1	-1.2725	-0.5522
Depth*WellPosition	D	2	S	2	-0.8017	-0.2201
Depth*WellPosition	D	2	S	3	-0.4804	0.1841
Depth*WellPosition	D	3	S	1	-1.5164	-0.7888
Depth*WellPosition	D	3	S	2	-1.0976	-0.4047
Depth*WellPosition	D	3	S	3	-0.6800	-0.09678
Depth*WellPosition	S	1	S	2	0.02539	0.7775
Depth*WellPosition	S	1	S	3	0.3974	1.1311
Depth*WellPosition	S	2	S	3	0.01294	0.7126

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	967	0.56	0.4561
Depth*WellPosition		2	1	967	11.89	0.0006
Depth*WellPosition		3	1	967	6.83	0.0091
Depth*WellPosition	D		2	967	32.18	<.0001
Depth*WellPosition	S		2	967	8.38	0.0002

+++++

The SAS System 134

Block=3

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnCl
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	18	Jav3-a1d Jav3-a1s Jav3-a2d Jav3-a2s Jav3-a3d Jav3-a3s Jav3-b1d Jav3-b1s Jav3-b2d Jav3-b2s Jav3-b3d Jav3-b3s Jav3-c1d Jav3-c1s Jav3-c2d Jav3-c2s Jav3-c3d Jav3-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51
Block	1	3
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644 16658 16671 16708 16736 16771 16813 16841 16869 16904 16933 16960 17023 17064 17092 17126 17155 17190 17218 17246 17257 17287 17318 17348 17398 17426 17463 17494 17617 17644 17665 17693 17721 17750 17799 17827 17855 17883 17920 17945 17980 18008 18045 18077 18099 18127 18155 18190 18218 18246 18281 18311 18337 18374 18400

+++++

The SAS System 135

Block=3

The Mixed Procedure

Dimensions

Covariance Parameters	5
Columns in X	12
Columns in Z	52
Subjects	1
Max Obs Per Subject	1044

Number of Observations

Number of Observations Read 1044
 Number of Observations Used 952
 Number of Observations Not Used 92

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	2248.74073665	
1	3	1501.43073959	0.01386126
2	2	1499.76780421	0.00008729
3	1	1499.75705143	0.00000023
4	1	1499.75702412	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0.1617	0.1763	0.92	0.1796
WellPositio*Transect		0.02542	0.03051	0.83	0.2024
week		0.06878	0.01887	3.64	0.0001
AR(1)	SampleID	0.6432	0.02744	23.44	<.0001
Residual		0.4276	0.03253	13.15	<.0001

Fit Statistics

-2 Res Log Likelihood 1499.8
 AIC (smaller is better) 1509.8
 AICC (smaller is better) 1509.8
 BIC (smaller is better) 1505.3

+++++

The SAS System 136

Block=3

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	9.37	0.0310
Depth	1	903	1.84	0.1757
Depth*WellPosition	2	903	0.23	0.7963

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
--------	-------	---------------	----------	----------------	----	---------	---------

WellPosition		1	2.0428	0.2664	4	7.67	0.0016
WellPosition		2	1.7066	0.2646	4	6.45	0.0030
WellPosition		3	1.3074	0.2641	4	4.95	0.0078
Depth	D		1.7462	0.2488	903	7.02	<.0001
Depth	S		1.6249	0.2517	903	6.45	<.0001
Depth*WellPosition	D	1	2.1469	0.2733	903	7.85	<.0001
Depth*WellPosition	D	2	1.7480	0.2719	903	6.43	<.0001
Depth*WellPosition	D	3	1.3437	0.2717	903	4.95	<.0001
Depth*WellPosition	S	1	1.9386	0.2838	903	6.83	<.0001
Depth*WellPosition	S	2	1.6652	0.2784	903	5.98	<.0001
Depth*WellPosition	S	3	1.2710	0.2767	903	4.59	<.0001

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	1.3032	2.7824
WellPosition		2	0.05	0.9721	2.4412
WellPosition		3	0.05	0.5742	2.0406
Depth	D		0.05	1.2579	2.2345
Depth	S		0.05	1.1309	2.1190
Depth*WellPosition	D	1	0.05	1.6105	2.6834
Depth*WellPosition	D	2	0.05	1.2144	2.2817
Depth*WellPosition	D	3	0.05	0.8105	1.8770
Depth*WellPosition	S	1	0.05	1.3816	2.4955
Depth*WellPosition	S	2	0.05	1.1188	2.2116
Depth*WellPosition	S	3	0.05	0.7279	1.8142

+++++

The SAS System

137

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
WellPosition		1		2	0.3361	0.1711	4
WellPosition		1		3	0.7354	0.1704	4
WellPosition		2		3	0.3992	0.1676	4
Depth	D		S		0.1213	0.08951	903
Depth*WellPosition	D	1	D	2	0.3989	0.1926	903
Depth*WellPosition	D	1	D	3	0.8032	0.1924	903
Depth*WellPosition	D	1	S	1	0.2084	0.1632	903
Depth*WellPosition	D	1	S	2	0.4817	0.2014	903
Depth*WellPosition	D	1	S	3	0.8759	0.1992	903
Depth*WellPosition	D	2	D	3	0.4043	0.1903	903
Depth*WellPosition	D	2	S	1	-0.1905	0.2070	903
Depth*WellPosition	D	2	S	2	0.08283	0.1513	903
Depth*WellPosition	D	2	S	3	0.4770	0.1973	903
Depth*WellPosition	D	3	S	1	-0.5948	0.2067	903
Depth*WellPosition	D	3	S	2	-0.3215	0.1994	903
Depth*WellPosition	D	3	S	3	0.07271	0.1480	903
Depth*WellPosition	S	1	S	2	0.2734	0.2146	903
Depth*WellPosition	S	1	S	3	0.6675	0.2126	903
Depth*WellPosition	S	2	S	3	0.3942	0.2055	903

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	1.97	0.1208	0.05
WellPosition		1		3	4.32	0.0125	0.05
WellPosition		2		3	2.38	0.0758	0.05
Depth	D		S		1.36	0.1757	0.05
Depth*WellPosition	D	1	D	2	2.07	0.0386	0.05
Depth*WellPosition	D	1	D	3	4.18	<.0001	0.05
Depth*WellPosition	D	1	S	1	1.28	0.2021	0.05
Depth*WellPosition	D	1	S	2	2.39	0.0170	0.05
Depth*WellPosition	D	1	S	3	4.40	<.0001	0.05
Depth*WellPosition	D	2	D	3	2.12	0.0339	0.05
Depth*WellPosition	D	2	S	1	-0.92	0.3575	0.05
Depth*WellPosition	D	2	S	2	0.55	0.5843	0.05
Depth*WellPosition	D	2	S	3	2.42	0.0158	0.05
Depth*WellPosition	D	3	S	1	-2.88	0.0041	0.05
Depth*WellPosition	D	3	S	2	-1.61	0.1072	0.05
Depth*WellPosition	D	3	S	3	0.49	0.6232	0.05
Depth*WellPosition	S	1	S	2	1.27	0.2031	0.05
Depth*WellPosition	S	1	S	3	3.14	0.0017	0.05

+++++

The SAS System

138

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	1.92	0.0555	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
WellPosition		1		2	-0.1388	0.8111
WellPosition		1		3	0.2624	1.2084
WellPosition		2		3	-0.06609	0.8645
Depth	D		S		-0.05437	0.2970
Depth*WellPosition	D	1	D	2	0.02089	0.7769
Depth*WellPosition	D	1	D	3	0.4257	1.1807
Depth*WellPosition	D	1	S	1	-0.1120	0.5287
Depth*WellPosition	D	1	S	2	0.08638	0.8771
Depth*WellPosition	D	1	S	3	0.4850	1.2668
Depth*WellPosition	D	2	D	3	0.03087	0.7777
Depth*WellPosition	D	2	S	1	-0.5967	0.2156
Depth*WellPosition	D	2	S	2	-0.2142	0.3798
Depth*WellPosition	D	2	S	3	0.08971	0.8643
Depth*WellPosition	D	3	S	1	-1.0005	-0.1891
Depth*WellPosition	D	3	S	2	-0.7128	0.06984
Depth*WellPosition	D	3	S	3	-0.2177	0.3631
Depth*WellPosition	S	1	S	2	-0.1478	0.6946
Depth*WellPosition	S	1	S	3	0.2502	1.0849

Depth*WellPosition S 2 S 3 -0.00923 0.7976

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	903	1.63	0.2021
Depth*WellPosition		2	1	903	0.30	0.5843
Depth*WellPosition		3	1	903	0.24	0.6232
Depth*WellPosition	D		2	903	8.72	0.0002
Depth*WellPosition	S		2	903	5.05	0.0066

SAS Output for NO3-N/Cl- Ratio Analysis

+++++

The SAS System 139

Block=.

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnNC1

+++++

The SAS System 140

Block=1

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnNC1
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	15	Jav1-a1d Jav1-a1s Jav1-a2s Jav1-a3s Jav1-b1d Jav1-b1s Jav1-b2s Jav1-b3d Jav1-b3s Jav1-c1d Jav1-c1s Jav1-c2d

```

                Jav1-c2s Jav1-c3d Jav1-c3s
Depth           2       D S
WellPosition    3       1 2 3
Transect        3       A B C
week           40      2 3 4 6 7 8 10 11 12 13 14 15
                  16 17 18 19 20 21 22 23 24 26
                  27 28 29 30 31 32 33 34 37 38
                  39 42 43 46 47 48 50 51
Block           1       1
Date           69      16448 16462 16476 16490 16505
                  16518 16532 16546 16561 16574
                  16589 16602 16616 16630 16644
                  16658 16671 16708 16736 16771
                  16813 16841 16869 16904 16933
                  16960 17023 17064 17092 17126
                  17155 17190 17218 17246 17257
                  17287 17318 17348 17398 17426
                  17463 17494 17617 17644 17665
                  17693 17721 17750 17799 17827
                  17855 17883 17920 17945 17980
                  18008 18045 18077 18099 18127
                  18155 18190 18218 18246 18281
                  18311 18337 18374 18400

```

+++++

The SAS System

141

Block=1

The Mixed Procedure

Dimensions

```

Covariance Parameters      5
Columns in X                12
Columns in Z                52
Subjects                    1
Max Obs Per Subject        884

```

Number of Observations

```

Number of Observations Read      884
Number of Observations Used      795
Number of Observations Not Used  89

```

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	2774.92104658	
1	3	2158.71481779	100.23204550
2	1	2141.54021717	25.05157247
3	1	2140.51033862	19.29962200
4	1	2136.86287653	2.79015723
5	2	2136.18952957	0.03698134
6	2	2135.40003343	0.00208599
7	2	2134.95383023	0.00044396
8	1	2134.80202096	0.00000003
9	1	2134.80201215	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0.2838	0.5591	0.51	0.3059
WellPositio*Transect		0.6913	0.5161	1.34	0.0902
week		0.04140	0.01688	2.45	0.0071
AR(1)	SampleID	0.5348	0.03483	15.36	<.0001
Residual		1.1190	0.08197	13.65	<.0001

+++++

The SAS System 142

Block=1

The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood	2134.8
AIC (smaller is better)	2144.8
AICC (smaller is better)	2144.9
BIC (smaller is better)	2140.3

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	9.87	0.0284
Depth	1	746	0.03	0.8650
Depth*WellPosition	2	746	2.31	0.0998

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	0.1194	0.5851	4	0.20	0.8482
WellPosition		2	-0.7087	0.5966	4	-1.19	0.3006
WellPosition		3	-2.8986	0.5841	4	-4.96	0.0077
Depth	D		-1.1489	0.4355	746	-2.64	0.0085
Depth	S		-1.1763	0.4268	746	-2.76	0.0060
Depth*WellPosition	D	1	-0.1002	0.5883	746	-0.17	0.8648
Depth*WellPosition	D	2	-0.5420	0.6491	746	-0.84	0.4040
Depth*WellPosition	D	3	-2.8046	0.6035	746	-4.65	<.0001
Depth*WellPosition	S	1	0.3390	0.6086	746	0.56	0.5776

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	-1.5050	1.7439
WellPosition		2	0.05	-2.3650	0.9476

WellPosition		3	0.05	-4.5202	-1.2770
Depth	D		0.05	-2.0039	-0.2940
Depth	S		0.05	-2.0142	-0.3385
Depth*WellPosition	D	1	0.05	-1.2550	1.0547
Depth*WellPosition	D	2	0.05	-1.8163	0.7323
Depth*WellPosition	D	3	0.05	-3.9894	-1.6198
Depth*WellPosition	S	1	0.05	-0.8557	1.5338

+++++

The SAS System 143

Block=1

The Mixed Procedure

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
Depth*WellPosition	S	2	-0.8754	0.5892	746	-1.49	0.1377
Depth*WellPosition	S	3	-2.9926	0.5886	746	-5.08	<.0001

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
Depth*WellPosition	S	2	0.05	-2.0320	0.2812
Depth*WellPosition	S	3	0.05	-4.1481	-1.8372

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Estimate	Standard Error	DF
WellPosition		1		2	0.8282	0.7116	4
WellPosition		1		3	3.0181	0.7012	4
WellPosition		2		3	2.1899	0.7108	4
Depth	D		S		0.02741	0.1612	746

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	1.16	0.3092	0.05
WellPosition		1		3	4.30	0.0126	0.05
WellPosition		2		3	3.08	0.0369	0.05
Depth	D		S		0.17	0.8650	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
WellPosition		1		2	-1.1477	2.8040
WellPosition		1		3	1.0711	4.9650
WellPosition		2		3	0.2164	4.1634
Depth	D		S		-0.2891	0.3439

+++++

The SAS System

144

Block=1

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
Depth*WellPosition	D	1	D	2	0.4418	0.7588	746
Depth*WellPosition	D	1	D	3	2.7045	0.7202	746
Depth*WellPosition	D	1	S	1	-0.4392	0.2521	746
Depth*WellPosition	D	1	S	2	0.7753	0.7082	746
Depth*WellPosition	D	1	S	3	2.8925	0.7077	746
Depth*WellPosition	D	2	D	3	2.2626	0.7705	746
Depth*WellPosition	D	2	S	1	-0.8810	0.7744	746
Depth*WellPosition	D	2	S	2	0.3334	0.3366	746
Depth*WellPosition	D	2	S	3	2.4506	0.7590	746
Depth*WellPosition	D	3	S	1	-3.1437	0.7368	746
Depth*WellPosition	D	3	S	2	-1.9292	0.7209	746
Depth*WellPosition	D	3	S	3	0.1880	0.2384	746
Depth*WellPosition	S	1	S	2	1.2145	0.7250	746
Depth*WellPosition	S	1	S	3	3.3317	0.7246	746
Depth*WellPosition	S	2	S	3	2.1172	0.7084	746

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	D	1	D	2	0.58	0.5605	0.05
Depth*WellPosition	D	1	D	3	3.76	0.0002	0.05
Depth*WellPosition	D	1	S	1	-1.74	0.0819	0.05
Depth*WellPosition	D	1	S	2	1.09	0.2740	0.05
Depth*WellPosition	D	1	S	3	4.09	<.0001	0.05
Depth*WellPosition	D	2	D	3	2.94	0.0034	0.05
Depth*WellPosition	D	2	S	1	-1.14	0.2556	0.05
Depth*WellPosition	D	2	S	2	0.99	0.3223	0.05
Depth*WellPosition	D	2	S	3	3.23	0.0013	0.05
Depth*WellPosition	D	3	S	1	-4.27	<.0001	0.05
Depth*WellPosition	D	3	S	2	-2.68	0.0076	0.05
Depth*WellPosition	D	3	S	3	0.79	0.4305	0.05
Depth*WellPosition	S	1	S	2	1.68	0.0943	0.05
Depth*WellPosition	S	1	S	3	4.60	<.0001	0.05
Depth*WellPosition	S	2	S	3	2.99	0.0029	0.05

+++++

The SAS System

145

Block=1

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
--------	-------	---------------	--------	----------------	-------	-------

Depth*WellPosition	D	1	D	2	-1.0477	1.9314
Depth*WellPosition	D	1	D	3	1.2906	4.1183
Depth*WellPosition	D	1	S	1	-0.9341	0.05574
Depth*WellPosition	D	1	S	2	-0.6150	2.1655
Depth*WellPosition	D	1	S	3	1.5032	4.2817
Depth*WellPosition	D	2	D	3	0.7501	3.7752
Depth*WellPosition	D	2	S	1	-2.4014	0.6393
Depth*WellPosition	D	2	S	2	-0.3275	0.9943
Depth*WellPosition	D	2	S	3	0.9606	3.9406
Depth*WellPosition	D	3	S	1	-4.5901	-1.6972
Depth*WellPosition	D	3	S	2	-3.3444	-0.5140
Depth*WellPosition	D	3	S	3	-0.2800	0.6560
Depth*WellPosition	S	1	S	2	-0.2088	2.6377
Depth*WellPosition	S	1	S	3	1.9093	4.7541
Depth*WellPosition	S	2	S	3	0.7265	3.5079

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	746	3.03	0.0819
Depth*WellPosition		2	1	746	0.98	0.3223
Depth*WellPosition		3	1	746	0.62	0.4305
Depth*WellPosition	D		2	746	7.87	0.0004
Depth*WellPosition	S		2	746	10.93	<.0001

+++++

The SAS System 146

Block=2

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnNC1
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	18	Jav2-a1d Jav2-a1s Jav2-a2d Jav2-a2s Jav2-a3d Jav2-a3s Jav2-b1d Jav2-b1s Jav2-b2d Jav2-b2s Jav2-b3d Jav2-b3s Jav2-c1d Jav2-c1s Jav2-c2d Jav2-c2s Jav2-c3d Jav2-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C

```

week          40    2 3 4 6 7 8 10 11 12 13 14 15
                16 17 18 19 20 21 22 23 24 26
                27 28 29 30 31 32 33 34 37 38
                39 42 43 46 47 48 50 51
Block         1
Date          69    16448 16462 16476 16490 16505
                16518 16532 16546 16561 16574
                16589 16602 16616 16630 16644
                16658 16671 16708 16736 16771
                16813 16841 16869 16904 16933
                16960 17023 17064 17092 17126
                17155 17190 17218 17246 17257
                17287 17318 17348 17398 17426
                17463 17494 17617 17644 17665
                17693 17721 17750 17799 17827
                17855 17883 17920 17945 17980
                18008 18045 18077 18099 18127
                18155 18190 18218 18246 18281
                18311 18337 18374 18400

```

+++++

The SAS System 147

Block=2

The Mixed Procedure

Dimensions

```

Covariance Parameters      5
Columns in X                12
Columns in Z                52
Subjects                    1
Max Obs Per Subject        1111

```

Number of Observations

```

Number of Observations Read      1111
Number of Observations Used      1016
Number of Observations Not Used   95

```

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	3752.88653040	
1	3	2647.25492122	0.00038964
2	1	2647.09553655	0.00000632
3	1	2647.09293155	0.00000003
4	1	2647.09291984	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr > Z
----------	---------	----------	----------------	---------	--------

Transect		1.5632	1.6090	0.97	0.1656
WellPositio*Transect		0.09257	0.09534	0.97	0.1658
week		0.08566	0.02806	3.05	0.0011
AR(1)	SampleID	0.6280	0.02832	22.18	<.0001
Residual		1.1994	0.08742	13.72	<.0001

Fit Statistics

-2 Res Log Likelihood	2647.1
AIC (smaller is better)	2657.1
AICC (smaller is better)	2657.2
BIC (smaller is better)	2652.6

+++++

The SAS System 148

Block=2

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	10.05	0.0276
Depth	1	967	14.35	0.0002
Depth*WellPosition	2	967	2.99	0.0508

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	-0.5949	0.7555	4	-0.79	0.4750
WellPosition		2	-1.9504	0.7546	4	-2.58	0.0610
WellPosition		3	-1.1270	0.7535	4	-1.50	0.2090
Depth	D		-0.9607	0.7364	967	-1.30	0.1923
Depth	S		-1.4875	0.7382	967	-2.01	0.0442
Depth*WellPosition	D	1	-0.5692	0.7617	967	-0.75	0.4551
Depth*WellPosition	D	2	-1.5102	0.7608	967	-1.99	0.0474
Depth*WellPosition	D	3	-0.8029	0.7618	967	-1.05	0.2922
Depth*WellPosition	S	1	-0.6207	0.7708	967	-0.81	0.4209
Depth*WellPosition	S	2	-2.3906	0.7663	967	-3.12	0.0019
Depth*WellPosition	S	3	-1.4512	0.7628	967	-1.90	0.0574

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	-2.6926	1.5027
WellPosition		2	0.05	-4.0454	0.1446
WellPosition		3	0.05	-3.2190	0.9650
Depth	D		0.05	-2.4058	0.4843
Depth	S		0.05	-2.9362	-0.03881
Depth*WellPosition	D	1	0.05	-2.0639	0.9256
Depth*WellPosition	D	2	0.05	-3.0032	-0.01718
Depth*WellPosition	D	3	0.05	-2.2979	0.6921
Depth*WellPosition	S	1	0.05	-2.1334	0.8920

Depth*WellPosition	S	2	0.05	-3.8944	-0.8869
Depth*WellPosition	S	3	0.05	-2.9482	0.04578

+++++

The SAS System 149

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Estimate	Standard Error	DF
WellPosition		1		2	1.3555	0.3051	4
WellPosition		1		3	0.5321	0.3025	4
WellPosition		2		3	-0.8234	0.3002	4
Depth	D		S		0.5268	0.1391	967
Depth*WellPosition	D	1	D	2	0.9410	0.3348	967
Depth*WellPosition	D	1	D	3	0.2337	0.3370	967
Depth*WellPosition	D	1	S	1	0.05156	0.2562	967
Depth*WellPosition	D	1	S	2	1.8215	0.3470	967
Depth*WellPosition	D	1	S	3	0.8820	0.3393	967
Depth*WellPosition	D	2	D	3	-0.7073	0.3350	967
Depth*WellPosition	D	2	S	1	-0.8895	0.3549	967
Depth*WellPosition	D	2	S	2	0.8804	0.2334	967
Depth*WellPosition	D	2	S	3	-0.05900	0.3373	967
Depth*WellPosition	D	3	S	1	-0.1821	0.3570	967
Depth*WellPosition	D	3	S	2	1.5878	0.3472	967
Depth*WellPosition	D	3	S	3	0.6483	0.2314	967
Depth*WellPosition	S	1	S	2	1.7699	0.3661	967
Depth*WellPosition	S	1	S	3	0.8305	0.3590	967
Depth*WellPosition	S	2	S	3	-0.9394	0.3493	967

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	4.44	0.0113	0.05
WellPosition		1		3	1.76	0.1534	0.05
WellPosition		2		3	-2.74	0.0517	0.05
Depth	D		S		3.79	0.0002	0.05
Depth*WellPosition	D	1	D	2	2.81	0.0050	0.05
Depth*WellPosition	D	1	D	3	0.69	0.4882	0.05
Depth*WellPosition	D	1	S	1	0.20	0.8405	0.05
Depth*WellPosition	D	1	S	2	5.25	<.0001	0.05
Depth*WellPosition	D	1	S	3	2.60	0.0095	0.05
Depth*WellPosition	D	2	D	3	-2.11	0.0350	0.05
Depth*WellPosition	D	2	S	1	-2.51	0.0124	0.05
Depth*WellPosition	D	2	S	2	3.77	0.0002	0.05
Depth*WellPosition	D	2	S	3	-0.17	0.8612	0.05
Depth*WellPosition	D	3	S	1	-0.51	0.6101	0.05
Depth*WellPosition	D	3	S	2	4.57	<.0001	0.05
Depth*WellPosition	D	3	S	3	2.80	0.0052	0.05
Depth*WellPosition	S	1	S	2	4.83	<.0001	0.05
Depth*WellPosition	S	1	S	3	2.31	0.0209	0.05

+++++

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	-2.69	0.0073	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
WellPosition		1		2	0.5084	2.2026
WellPosition		1		3	-0.3077	1.3719
WellPosition		2		3	-1.6568	0.01004
Depth	D		S		0.2539	0.7997
Depth*WellPosition	D	1	D	2	0.2841	1.5980
Depth*WellPosition	D	1	D	3	-0.4277	0.8951
Depth*WellPosition	D	1	S	1	-0.4511	0.5543
Depth*WellPosition	D	1	S	2	1.1406	2.5024
Depth*WellPosition	D	1	S	3	0.2162	1.5479
Depth*WellPosition	D	2	D	3	-1.3647	-0.04996
Depth*WellPosition	D	2	S	1	-1.5859	-0.1930
Depth*WellPosition	D	2	S	2	0.4224	1.3385
Depth*WellPosition	D	2	S	3	-0.7209	0.6029
Depth*WellPosition	D	3	S	1	-0.8828	0.5185
Depth*WellPosition	D	3	S	2	0.9065	2.2691
Depth*WellPosition	D	3	S	3	0.1942	1.1025
Depth*WellPosition	S	1	S	2	1.0514	2.4884
Depth*WellPosition	S	1	S	3	0.1259	1.5351
Depth*WellPosition	S	2	S	3	-1.6249	-0.2540

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	967	0.04	0.8405
Depth*WellPosition		2	1	967	14.23	0.0002
Depth*WellPosition		3	1	967	7.85	0.0052
Depth*WellPosition	D		2	967	4.30	0.0139
Depth*WellPosition	S		2	967	11.74	<.0001

+++++

Block=3

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnNC1

Covariance Structures	Variance Components,
	Autoregressive
Subject Effect	SampleID
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
SampleID	18	Jav3-a1d Jav3-a1s Jav3-a2d Jav3-a2s Jav3-a3d Jav3-a3s Jav3-b1d Jav3-b1s Jav3-b2d Jav3-b2s Jav3-b3d Jav3-b3s Jav3-c1d Jav3-c1s Jav3-c2d Jav3-c2s Jav3-c3d Jav3-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51
Block	1	3
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644 16658 16671 16708 16736 16771 16813 16841 16869 16904 16933 16960 17023 17064 17092 17126 17155 17190 17218 17246 17257 17287 17318 17348 17398 17426 17463 17494 17617 17644 17665 17693 17721 17750 17799 17827 17855 17883 17920 17945 17980 18008 18045 18077 18099 18127 18155 18190 18218 18246 18281 18311 18337 18374 18400

+++++

The SAS System 152

Block=3

The Mixed Procedure

Dimensions

Covariance Parameters	5
Columns in X	12
Columns in Z	52
Subjects	1
Max Obs Per Subject	1044

Number of Observations

Number of Observations Read	1044
Number of Observations Used	948

Number of Observations Not Used 96

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	2952.90375046	
1	3	2477.53921146	0.00009030
2	1	2477.50181216	0.00000331
3	1	2477.50054498	0.00000001

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0.004821	0.06479	0.07	0.4703
WellPositio*Transect		0.1034	0.1047	0.99	0.1618
week		0.06949	0.02483	2.80	0.0026
AR(1)	SampleID	0.6117	0.02721	22.48	<.0001
Residual		1.1795	0.08360	14.11	<.0001

Fit Statistics

-2 Res Log Likelihood	2477.5
AIC (smaller is better)	2487.5
AICC (smaller is better)	2487.6
BIC (smaller is better)	2483.0

The SAS System 153

Block=3

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	8.51	0.0362
Depth	1	899	34.11	<.0001
Depth*WellPosition	2	899	6.35	0.0018

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	-0.5683	0.2342	4	-2.43	0.0722
WellPosition		2	-1.8066	0.2289	4	-7.89	0.0014
WellPosition		3	-1.5497	0.2275	4	-6.81	0.0024
Depth	D		-0.8949	0.1528	899	-5.86	<.0001
Depth	S		-1.7215	0.1641	899	-10.49	<.0001

Depth*WellPosition	D	1	-0.4887	0.2535	899	-1.93	0.0542
Depth*WellPosition	D	2	-1.1020	0.2496	899	-4.42	<.0001
Depth*WellPosition	D	3	-1.0941	0.2491	899	-4.39	<.0001
Depth*WellPosition	S	1	-0.6479	0.2807	899	-2.31	0.0212
Depth*WellPosition	S	2	-2.5112	0.2668	899	-9.41	<.0001
Depth*WellPosition	S	3	-2.0053	0.2625	899	-7.64	<.0001

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	-1.2184	0.08186
WellPosition		2	0.05	-2.4422	-1.1709
WellPosition		3	0.05	-2.1814	-0.9179
Depth	D		0.05	-1.1948	-0.5951
Depth	S		0.05	-2.0435	-1.3994
Depth*WellPosition	D	1	0.05	-0.9862	0.008871
Depth*WellPosition	D	2	0.05	-1.5918	-0.6122
Depth*WellPosition	D	3	0.05	-1.5831	-0.6052
Depth*WellPosition	S	1	0.05	-1.1988	-0.09695
Depth*WellPosition	S	2	0.05	-3.0349	-1.9875
Depth*WellPosition	S	3	0.05	-2.5204	-1.4901

+++++

The SAS System 154

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
WellPosition		1		2	1.2383	0.3160	4
WellPosition		1		3	0.9814	0.3150	4
WellPosition		2		3	-0.2569	0.3112	4
Depth	D		S		0.8265	0.1415	899
Depth*WellPosition	D	1	D	2	0.6133	0.3455	899
Depth*WellPosition	D	1	D	3	0.6054	0.3452	899
Depth*WellPosition	D	1	S	1	0.1592	0.2585	899
Depth*WellPosition	D	1	S	2	2.0225	0.3580	899
Depth*WellPosition	D	1	S	3	1.5166	0.3548	899
Depth*WellPosition	D	2	D	3	-0.00787	0.3423	899
Depth*WellPosition	D	2	S	1	-0.4541	0.3658	899
Depth*WellPosition	D	2	S	2	1.4092	0.2394	899
Depth*WellPosition	D	2	S	3	0.9033	0.3522	899
Depth*WellPosition	D	3	S	1	-0.4462	0.3655	899
Depth*WellPosition	D	3	S	2	1.4171	0.3550	899
Depth*WellPosition	D	3	S	3	0.9111	0.2342	899
Depth*WellPosition	S	1	S	2	1.8633	0.3770	899
Depth*WellPosition	S	1	S	3	1.3574	0.3741	899
Depth*WellPosition	S	2	S	3	-0.5059	0.3639	899

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
--------	-------	---------------	--------	----------------	---------	---------	-------

WellPosition		1		2	3.92	0.0173	0.05
WellPosition		1		3	3.12	0.0357	0.05
WellPosition		2		3	-0.83	0.4555	0.05
Depth	D		S		5.84	<.0001	0.05
Depth*WellPosition	D	1	D	2	1.77	0.0762	0.05
Depth*WellPosition	D	1	D	3	1.75	0.0798	0.05
Depth*WellPosition	D	1	S	1	0.62	0.5381	0.05
Depth*WellPosition	D	1	S	2	5.65	<.0001	0.05
Depth*WellPosition	D	1	S	3	4.27	<.0001	0.05
Depth*WellPosition	D	2	D	3	-0.02	0.9817	0.05
Depth*WellPosition	D	2	S	1	-1.24	0.2148	0.05
Depth*WellPosition	D	2	S	2	5.89	<.0001	0.05
Depth*WellPosition	D	2	S	3	2.56	0.0105	0.05
Depth*WellPosition	D	3	S	1	-1.22	0.2224	0.05
Depth*WellPosition	D	3	S	2	3.99	<.0001	0.05
Depth*WellPosition	D	3	S	3	3.89	0.0001	0.05
Depth*WellPosition	S	1	S	2	4.94	<.0001	0.05
Depth*WellPosition	S	1	S	3	3.63	0.0003	0.05

+++++

The SAS System

155

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	-1.39	0.1648	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
WellPosition		1		2	0.3611	2.1155
WellPosition		1		3	0.1068	1.8560
WellPosition		2		3	-1.1210	0.6072
Depth	D		S		0.5488	1.1043
Depth*WellPosition	D	1	D	2	-0.06484	1.2915
Depth*WellPosition	D	1	D	3	-0.07205	1.2829
Depth*WellPosition	D	1	S	1	-0.3481	0.6665
Depth*WellPosition	D	1	S	2	1.3200	2.7251
Depth*WellPosition	D	1	S	3	0.8202	2.2129
Depth*WellPosition	D	2	D	3	-0.6797	0.6639
Depth*WellPosition	D	2	S	1	-1.1720	0.2638
Depth*WellPosition	D	2	S	2	0.9393	1.8791
Depth*WellPosition	D	2	S	3	0.2121	1.5944
Depth*WellPosition	D	3	S	1	-1.1635	0.2711
Depth*WellPosition	D	3	S	2	0.7203	2.1138
Depth*WellPosition	D	3	S	3	0.4515	1.3707
Depth*WellPosition	S	1	S	2	1.1235	2.6031
Depth*WellPosition	S	1	S	3	0.6232	2.0915
Depth*WellPosition	S	2	S	3	-1.2202	0.2083

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	899	0.38	0.5381
Depth*WellPosition		2	1	899	34.64	<.0001
Depth*WellPosition		3	1	899	15.14	0.0001
Depth*WellPosition	D		2	899	2.06	0.1276
Depth*WellPosition	S		2	899	12.92	<.0001

SAS output for DOC Concentration Analysis

+++++

The SAS System 174

Block=.

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnDOC

+++++

The SAS System 175

Block=1

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnDOC
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	15	Jav1-a1d Jav1-a1s Jav1-a2s Jav1-a3s Jav1-b1d Jav1-b1s Jav1-b2s Jav1-b3d Jav1-b3s Jav1-c1d Jav1-c1s Jav1-c2d Jav1-c2s Jav1-c3d Jav1-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51

```

Block          1      1
Date          69      16448 16462 16476 16490 16505
              16518 16532 16546 16561 16574
              16589 16602 16616 16630 16644
              16658 16671 16708 16736 16771
              16813 16841 16869 16904 16933
              16960 17023 17064 17092 17126
              17155 17190 17218 17246 17257
              17287 17318 17348 17398 17426
              17463 17494 17617 17644 17665
              17693 17721 17750 17799 17827
              17855 17883 17920 17945 17980
              18008 18045 18077 18099 18127
              18155 18190 18218 18246 18281
              18311 18337 18374 18400

```

+++++

The SAS System 176

Block=1

The Mixed Procedure

Dimensions

```

Covariance Parameters          5
Columns in X                   12
Columns in Z                   52
Subjects                       1
Max Obs Per Subject           884

```

Number of Observations

```

Number of Observations Read      884
Number of Observations Used      90
Number of Observations Not Used  794

```

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	270.69645880	
1	2	227.08431910	2.19834132
2	3	226.89077191	.
3	3	225.13762478	0.03690855
4	2	224.58732427	0.00426827
5	1	224.42083331	0.00028552
6	1	224.41026605	0.00000246
7	1	224.41017946	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr > Z
Transect		5.85E-37	.	.	.

WellPositio*Transect		1.03E-18	.	.	.
week		0.4823	0.2650	1.82	0.0344
AR(1)	SampleID	0.6683	0.09828	6.80	<.0001
Residual		0.6908	0.1401	4.93	<.0001

+++++

The SAS System 177

Block=1

The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood	224.4
AIC (smaller is better)	230.4
AICC (smaller is better)	230.7
BIC (smaller is better)	227.7

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	0.20	0.8258
Depth	1	68	0.37	0.5429
Depth*WellPosition	2	68	1.53	0.2244

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	1.3234	0.3282	4	4.03	0.0157
WellPosition		2	1.3210	0.3331	4	3.97	0.0166
WellPosition		3	1.1611	0.3026	4	3.84	0.0185
Depth	D		1.1896	0.2924	68	4.07	0.0001
Depth	S		1.3474	0.2953	68	4.56	<.0001
Depth*WellPosition	D	1	1.0388	0.3383	68	3.07	0.0031
Depth*WellPosition	D	2	1.1577	0.4612	68	2.51	0.0145
Depth*WellPosition	D	3	1.3722	0.3758	68	3.65	0.0005
Depth*WellPosition	S	1	1.6080	0.4654	68	3.46	0.0010

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	0.4121	2.2347
WellPosition		2	0.05	0.3962	2.2458
WellPosition		3	0.05	0.3208	2.0013
Depth	D		0.05	0.6060	1.7731
Depth	S		0.05	0.7582	1.9366
Depth*WellPosition	D	1	0.05	0.3638	1.7139
Depth*WellPosition	D	2	0.05	0.2374	2.0781
Depth*WellPosition	D	3	0.05	0.6224	2.1221
Depth*WellPosition	S	1	0.05	0.6793	2.5367

+++++

The SAS System

178

Block=1

The Mixed Procedure

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
Depth*WellPosition	S	2	1.4843	0.3486	68	4.26	<.0001
Depth*WellPosition	S	3	0.9499	0.3370	68	2.82	0.0063

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
Depth*WellPosition	S	2	0.05	0.7887	2.1799
Depth*WellPosition	S	3	0.05	0.2775	1.6223

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Estimate	Standard Error	DF
WellPosition		1		2	0.002413	0.3407	4
WellPosition		1		3	0.1624	0.3088	4
WellPosition		2		3	0.1599	0.3033	4
Depth	D		S		-0.1578	0.2581	68

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	0.01	0.9947	0.05
WellPosition		1		3	0.53	0.6268	0.05
WellPosition		2		3	0.53	0.6259	0.05
Depth	D		S		-0.61	0.5429	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Lower	Upper
WellPosition		1		2	-0.9437	0.9485
WellPosition		1		3	-0.6949	1.0196
WellPosition		2		3	-0.6822	1.0021
Depth	D		S		-0.6728	0.3572

+++++

The SAS System

179

Block=1

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
Depth*WellPosition	D	1	D	2	-0.1189	0.4824	68
Depth*WellPosition	D	1	D	3	-0.3334	0.3988	68
Depth*WellPosition	D	1	S	1	-0.5692	0.4808	68
Depth*WellPosition	D	1	S	2	-0.4455	0.3739	68
Depth*WellPosition	D	1	S	3	0.08894	0.3630	68
Depth*WellPosition	D	2	D	3	-0.2145	0.4937	68
Depth*WellPosition	D	2	S	1	-0.4503	0.5665	68
Depth*WellPosition	D	2	S	2	-0.3266	0.4740	68
Depth*WellPosition	D	2	S	3	0.2078	0.4647	68
Depth*WellPosition	D	3	S	1	-0.2358	0.4958	68
Depth*WellPosition	D	3	S	2	-0.1121	0.3896	68
Depth*WellPosition	D	3	S	3	0.4224	0.3784	68
Depth*WellPosition	S	1	S	2	0.1237	0.4763	68
Depth*WellPosition	S	1	S	3	0.6581	0.4680	68
Depth*WellPosition	S	2	S	3	0.5344	0.3526	68

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	D	1	D	2	-0.25	0.8061	0.05
Depth*WellPosition	D	1	D	3	-0.84	0.4060	0.05
Depth*WellPosition	D	1	S	1	-1.18	0.2406	0.05
Depth*WellPosition	D	1	S	2	-1.19	0.2377	0.05
Depth*WellPosition	D	1	S	3	0.24	0.8072	0.05
Depth*WellPosition	D	2	D	3	-0.43	0.6652	0.05
Depth*WellPosition	D	2	S	1	-0.79	0.4294	0.05
Depth*WellPosition	D	2	S	2	-0.69	0.4932	0.05
Depth*WellPosition	D	2	S	3	0.45	0.6562	0.05
Depth*WellPosition	D	3	S	1	-0.48	0.6359	0.05
Depth*WellPosition	D	3	S	2	-0.29	0.7745	0.05
Depth*WellPosition	D	3	S	3	1.12	0.2683	0.05
Depth*WellPosition	S	1	S	2	0.26	0.7959	0.05
Depth*WellPosition	S	1	S	3	1.41	0.1642	0.05
Depth*WellPosition	S	2	S	3	1.52	0.1343	0.05

+++++

The SAS System 180

Block=1

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
Depth*WellPosition	D	1	D	2	-1.0816	0.8438
Depth*WellPosition	D	1	D	3	-1.1291	0.4623
Depth*WellPosition	D	1	S	1	-1.5286	0.3902
Depth*WellPosition	D	1	S	2	-1.1917	0.3007
Depth*WellPosition	D	1	S	3	-0.6355	0.8134
Depth*WellPosition	D	2	D	3	-1.1996	0.7706
Depth*WellPosition	D	2	S	1	-1.5807	0.6801

Depth*WellPosition	D	2	S	2	-1.2725	0.6193
Depth*WellPosition	D	2	S	3	-0.7195	1.1352
Depth*WellPosition	D	3	S	1	-1.2251	0.7536
Depth*WellPosition	D	3	S	2	-0.8895	0.6654
Depth*WellPosition	D	3	S	3	-0.3327	1.1774
Depth*WellPosition	S	1	S	2	-0.8267	1.0741
Depth*WellPosition	S	1	S	3	-0.2758	1.5920
Depth*WellPosition	S	2	S	3	-0.1693	1.2381

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	68	1.40	0.2406
Depth*WellPosition		2	1	68	0.47	0.4932
Depth*WellPosition		3	1	68	1.25	0.2683
Depth*WellPosition	D		2	68	0.35	0.7040
Depth*WellPosition	S		2	68	1.58	0.2131

+++++

The SAS System 181

Block=2

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnDOC
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	18	Jav2-a1d Jav2-a1s Jav2-a2d Jav2-a2s Jav2-a3d Jav2-a3s Jav2-b1d Jav2-b1s Jav2-b2d Jav2-b2s Jav2-b3d Jav2-b3s Jav2-c1d Jav2-c1s Jav2-c2d Jav2-c2s Jav2-c3d Jav2-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51
Block	1	2
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644

16658 16671 16708 16736 16771
 16813 16841 16869 16904 16933
 16960 17023 17064 17092 17126
 17155 17190 17218 17246 17257
 17287 17318 17348 17398 17426
 17463 17494 17617 17644 17665
 17693 17721 17750 17799 17827
 17855 17883 17920 17945 17980
 18008 18045 18077 18099 18127
 18155 18190 18218 18246 18281
 18311 18337 18374 18400

+++++

The SAS System 182

Block=2

The Mixed Procedure

Dimensions

Covariance Parameters	5
Columns in X	12
Columns in Z	52
Subjects	1
Max Obs Per Subject	1111

Number of Observations

Number of Observations Read	1111
Number of Observations Used	117
Number of Observations Not Used	994

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	359.13014452	
1	3	277.10338920	0.01808919
2	1	276.37382649	0.00026128
3	1	276.36457693	0.00000027
4	1	276.36456711	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0	.	.	.
WellPositio*Transect		0	.	.	.
week		0.8155	0.4543	1.80	0.0363
AR(1)	SampleID	-0.1020	0.2509	-0.41	0.6845
Residual		0.4951	0.06866	7.21	<.0001

Fit Statistics

```

-2 Res Log Likelihood      276.4
AIC (smaller is better)   282.4
AICC (smaller is better)  282.6
BIC (smaller is better)   279.7

```

+++++

```

The SAS System                                                    183

```

```

Block=2

```

```

The Mixed Procedure

```

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	3.25	0.1453
Depth	1	98	6.85	0.0103
Depth*WellPosition	2	98	2.18	0.1183

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	1.1869	0.3506	4	3.39	0.0277
WellPosition		2	0.8938	0.3393	4	2.63	0.0579
WellPosition		3	0.7283	0.3385	4	2.15	0.0978
Depth	D		1.1249	0.3298	98	3.41	0.0009
Depth	S		0.7478	0.3412	98	2.19	0.0308
Depth*WellPosition	D	1	1.1516	0.3508	98	3.28	0.0014
Depth*WellPosition	D	2	1.1907	0.3475	98	3.43	0.0009
Depth*WellPosition	D	3	1.0322	0.3496	98	2.95	0.0039
Depth*WellPosition	S	1	1.2222	0.4032	98	3.03	0.0031
Depth*WellPosition	S	2	0.5970	0.3689	98	1.62	0.1088
Depth*WellPosition	S	3	0.4243	0.3628	98	1.17	0.2450

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	0.2134	2.1604
WellPosition		2	0.05	-0.04808	1.8358
WellPosition		3	0.05	-0.2117	1.6682
Depth	D		0.05	0.4703	1.7794
Depth	S		0.05	0.07069	1.4250
Depth*WellPosition	D	1	0.05	0.4555	1.8477
Depth*WellPosition	D	2	0.05	0.5012	1.8803
Depth*WellPosition	D	3	0.05	0.3386	1.7259
Depth*WellPosition	S	1	0.05	0.4222	2.0223
Depth*WellPosition	S	2	0.05	-0.1351	1.3290
Depth*WellPosition	S	3	0.05	-0.2956	1.1443

+++++

```

The SAS System                                                    184

```

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Estimate	Standard Error	DF
WellPosition		1		2	0.2931	0.1822	4
WellPosition		1		3	0.4586	0.1800	4
WellPosition		2		3	0.1656	0.1596	4
Depth	D		S		0.3770	0.1441	98
Depth*WellPosition	D	1	D	2	-0.03913	0.1982	98
Depth*WellPosition	D	1	D	3	0.1194	0.2021	98
Depth*WellPosition	D	1	S	1	-0.07061	0.2818	98
Depth*WellPosition	D	1	S	2	0.5547	0.2340	98
Depth*WellPosition	D	1	S	3	0.7273	0.2243	98
Depth*WellPosition	D	2	D	3	0.1585	0.1966	98
Depth*WellPosition	D	2	S	1	-0.03148	0.2817	98
Depth*WellPosition	D	2	S	2	0.5938	0.2307	98
Depth*WellPosition	D	2	S	3	0.7664	0.2207	98
Depth*WellPosition	D	3	S	1	-0.1900	0.2817	98
Depth*WellPosition	D	3	S	2	0.4353	0.2325	98
Depth*WellPosition	D	3	S	3	0.6079	0.2217	98
Depth*WellPosition	S	1	S	2	0.6253	0.3035	98
Depth*WellPosition	S	1	S	3	0.7979	0.2962	98
Depth*WellPosition	S	2	S	3	0.1726	0.2507	98

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1		2	1.61	0.1831	0.05
WellPosition		1		3	2.55	0.0635	0.05
WellPosition		2		3	1.04	0.3582	0.05
Depth	D		S		2.62	0.0103	0.05
Depth*WellPosition	D	1	D	2	-0.20	0.8439	0.05
Depth*WellPosition	D	1	D	3	0.59	0.5561	0.05
Depth*WellPosition	D	1	S	1	-0.25	0.8027	0.05
Depth*WellPosition	D	1	S	2	2.37	0.0197	0.05
Depth*WellPosition	D	1	S	3	3.24	0.0016	0.05
Depth*WellPosition	D	2	D	3	0.81	0.4222	0.05
Depth*WellPosition	D	2	S	1	-0.11	0.9112	0.05
Depth*WellPosition	D	2	S	2	2.57	0.0116	0.05
Depth*WellPosition	D	2	S	3	3.47	0.0008	0.05
Depth*WellPosition	D	3	S	1	-0.67	0.5016	0.05
Depth*WellPosition	D	3	S	2	1.87	0.0641	0.05
Depth*WellPosition	D	3	S	3	2.74	0.0073	0.05
Depth*WellPosition	S	1	S	2	2.06	0.0421	0.05
Depth*WellPosition	S	1	S	3	2.69	0.0083	0.05

++++
The SAS System 185

Block=2

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	S	2	S	3	0.69	0.4928	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
WellPosition		1		2	-0.2129	0.7991
WellPosition		1		3	-0.04123	0.9585
WellPosition		2		3	-0.2776	0.6087
Depth	D		S		0.09112	0.6629
Depth*WellPosition	D	1	D	2	-0.4325	0.3543
Depth*WellPosition	D	1	D	3	-0.2816	0.5204
Depth*WellPosition	D	1	S	1	-0.6299	0.4887
Depth*WellPosition	D	1	S	2	0.09031	1.0190
Depth*WellPosition	D	1	S	3	0.2821	1.1725
Depth*WellPosition	D	2	D	3	-0.2317	0.5487
Depth*WellPosition	D	2	S	1	-0.5904	0.5275
Depth*WellPosition	D	2	S	2	0.1359	1.0517
Depth*WellPosition	D	2	S	3	0.3283	1.2045
Depth*WellPosition	D	3	S	1	-0.7489	0.3690
Depth*WellPosition	D	3	S	2	-0.02603	0.8966
Depth*WellPosition	D	3	S	3	0.1679	1.0479
Depth*WellPosition	S	1	S	2	0.02288	1.2276
Depth*WellPosition	S	1	S	3	0.2101	1.3857
Depth*WellPosition	S	2	S	3	-0.3249	0.6702

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	98	0.06	0.8027
Depth*WellPosition		2	1	98	6.62	0.0116
Depth*WellPosition		3	1	98	7.52	0.0073
Depth*WellPosition	D		2	98	0.35	0.7074
Depth*WellPosition	S		2	98	3.71	0.0280

+++++

The SAS System 186

Block=3

The Mixed Procedure

Model Information

Data Set WORK.SORTTIME
 Dependent Variable lnDOC
 Covariance Structures Variance Components,
 Autoregressive
 Subject Effect SampleID
 Estimation Method REML
 Residual Variance Method Profile
 Fixed Effects SE Method Model-Based
 Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
SampleID	18	Jav3-a1d Jav3-a1s Jav3-a2d Jav3-a2s Jav3-a3d Jav3-a3s Jav3-b1d Jav3-b1s Jav3-b2d Jav3-b2s Jav3-b3d Jav3-b3s Jav3-c1d Jav3-c1s Jav3-c2d Jav3-c2s Jav3-c3d Jav3-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51
Block	1	3
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644 16658 16671 16708 16736 16771 16813 16841 16869 16904 16933 16960 17023 17064 17092 17126 17155 17190 17218 17246 17257 17287 17318 17348 17398 17426 17463 17494 17617 17644 17665 17693 17721 17750 17799 17827 17855 17883 17920 17945 17980 18008 18045 18077 18099 18127 18155 18190 18218 18246 18281 18311 18337 18374 18400

+++++

The SAS System 187

Block=3

The Mixed Procedure

Dimensions

Covariance Parameters	5
Columns in X	12
Columns in Z	52
Subjects	1
Max Obs Per Subject	1044

Number of Observations

Number of Observations Read	1044
Number of Observations Used	113
Number of Observations Not Used	931

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	289.67680464	

1	4	154.82477601	0.12668133
2	1	151.61063636	0.02064771
3	1	151.09368771	0.00077772
4	1	151.07547077	0.00000152
5	1	151.07543601	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr Z
Transect		0	.	.	.
WellPositio*Transect		0	.	.	.
week		0.8268	0.4540	1.82	0.0343
AR(1)	SampleID	0.7859	0.07058	11.13	<.0001
Residual		0.2313	0.05272	4.39	<.0001

Fit Statistics

-2 Res Log Likelihood	151.1
AIC (smaller is better)	157.1
AICC (smaller is better)	157.3

+++++

The SAS System 188

Block=3

The Mixed Procedure

Fit Statistics

BIC (smaller is better)	154.4
-------------------------	-------

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
WellPosition	2	4	0.58	0.6023
Depth	1	94	0.14	0.7058
Depth*WellPosition	2	94	2.30	0.1054

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition		1	0.9950	0.3496	4	2.85	0.0466
WellPosition		2	1.1717	0.3462	4	3.38	0.0277
WellPosition		3	1.0159	0.3453	4	2.94	0.0423
Depth	D		1.0891	0.3357	94	3.24	0.0016
Depth	S		1.0326	0.3431	94	3.01	0.0034
Depth*WellPosition	D	1	0.7952	0.3633	94	2.19	0.0311
Depth*WellPosition	D	2	1.3209	0.3606	94	3.66	0.0004

Depth*WellPosition	D	3	1.1511	0.3600	94	3.20	0.0019
Depth*WellPosition	S	1	1.1948	0.3845	94	3.11	0.0025
Depth*WellPosition	S	2	1.0224	0.3766	94	2.71	0.0079

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
WellPosition		1	0.05	0.02429	1.9657
WellPosition		2	0.05	0.2104	2.1329
WellPosition		3	0.05	0.05726	1.9745
Depth	D		0.05	0.4225	1.7556
Depth	S		0.05	0.3514	1.7138
Depth*WellPosition	D	1	0.05	0.07386	1.5164
Depth*WellPosition	D	2	0.05	0.6049	2.0369
Depth*WellPosition	D	3	0.05	0.4362	1.8660
Depth*WellPosition	S	1	0.05	0.4314	1.9582
Depth*WellPosition	S	2	0.05	0.2747	1.7701

+++++

The SAS System 189

Block=3

The Mixed Procedure

Least Squares Means

Effect	Depth	Well Position	Estimate	Standard Error	DF	t Value	Pr > t
Depth*WellPosition	S	3	0.8807	0.3734	94	2.36	0.0204

Least Squares Means

Effect	Depth	Well Position	Alpha	Lower	Upper
Depth*WellPosition	S	3	0.05	0.1393	1.6221

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	Estimate	Standard Error	DF
WellPosition		1	2		-0.1767	0.1831	4
WellPosition		1	3		-0.02092	0.1808	4
WellPosition		2	3		0.1558	0.1758	4
Depth	D		S		0.05645	0.1491	94
Depth*WellPosition	D	1	D	2	-0.5258	0.2334	94

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	Well Position	t Value	Pr > t	Alpha
WellPosition		1	2		-0.97	0.3891	0.05
WellPosition		1	3		-0.12	0.9135	0.05
WellPosition		2	3		0.89	0.4257	0.05
Depth	D		S		0.38	0.7058	0.05

Depth*WellPosition D 1 D 2 -2.25 0.0266 0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
WellPosition		1		2	-0.6850	0.3316
WellPosition		1		3	-0.5230	0.4811
WellPosition		2		3	-0.3323	0.6439
Depth	D		S		-0.2396	0.3525
Depth*WellPosition	D	1	D	2	-0.9891	-0.06246

+++++

The SAS System

190

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Estimate	Standard Error	DF
Depth*WellPosition	D	1	D	3	-0.3559	0.2321	94
Depth*WellPosition	D	1	S	1	-0.3996	0.2658	94
Depth*WellPosition	D	1	S	2	-0.2272	0.2545	94
Depth*WellPosition	D	1	S	3	-0.08553	0.2496	94
Depth*WellPosition	D	2	D	3	0.1699	0.2288	94
Depth*WellPosition	D	2	S	1	0.1262	0.2650	94
Depth*WellPosition	D	2	S	2	0.2986	0.2535	94
Depth*WellPosition	D	2	S	3	0.4403	0.2487	94
Depth*WellPosition	D	3	S	1	-0.04369	0.2637	94
Depth*WellPosition	D	3	S	2	0.1287	0.2525	94
Depth*WellPosition	D	3	S	3	0.2704	0.2475	94
Depth*WellPosition	S	1	S	2	0.1724	0.2820	94
Depth*WellPosition	S	1	S	3	0.3141	0.2775	94
Depth*WellPosition	S	2	S	3	0.1417	0.2669	94

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	t Value	Pr > t	Alpha
Depth*WellPosition	D	1	D	3	-1.53	0.1286	0.05
Depth*WellPosition	D	1	S	1	-1.50	0.1361	0.05
Depth*WellPosition	D	1	S	2	-0.89	0.3742	0.05
Depth*WellPosition	D	1	S	3	-0.34	0.7326	0.05
Depth*WellPosition	D	2	D	3	0.74	0.4598	0.05
Depth*WellPosition	D	2	S	1	0.48	0.6351	0.05
Depth*WellPosition	D	2	S	2	1.18	0.2418	0.05
Depth*WellPosition	D	2	S	3	1.77	0.0799	0.05
Depth*WellPosition	D	3	S	1	-0.17	0.8688	0.05
Depth*WellPosition	D	3	S	2	0.51	0.6113	0.05
Depth*WellPosition	D	3	S	3	1.09	0.2775	0.05
Depth*WellPosition	S	1	S	2	0.61	0.5424	0.05
Depth*WellPosition	S	1	S	3	1.13	0.2606	0.05
Depth*WellPosition	S	2	S	3	0.53	0.5967	0.05

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
Depth*WellPosition	D	1	D	3	-0.8169	0.1050
Depth*WellPosition	D	1	S	1	-0.9274	0.1282
Depth*WellPosition	D	1	S	2	-0.7325	0.2781

+++++

The SAS System 191

Block=3

The Mixed Procedure

Differences of Least Squares Means

Effect	Depth	Well Position	_Depth	_Well Position	Lower	Upper
Depth*WellPosition	D	1	S	3	-0.5810	0.4100
Depth*WellPosition	D	2	D	3	-0.2845	0.6242
Depth*WellPosition	D	2	S	1	-0.3999	0.6523
Depth*WellPosition	D	2	S	2	-0.2047	0.8018
Depth*WellPosition	D	2	S	3	-0.05344	0.9340
Depth*WellPosition	D	3	S	1	-0.5673	0.4799
Depth*WellPosition	D	3	S	2	-0.3725	0.6300
Depth*WellPosition	D	3	S	3	-0.2211	0.7619
Depth*WellPosition	S	1	S	2	-0.3875	0.7324
Depth*WellPosition	S	1	S	3	-0.2369	0.8651
Depth*WellPosition	S	2	S	3	-0.3882	0.6716

Tests of Effect Slices

Effect	Depth	Well Position	Num DF	Den DF	F Value	Pr > F
Depth*WellPosition		1	1	94	2.26	0.1361
Depth*WellPosition		2	1	94	1.39	0.2418
Depth*WellPosition		3	1	94	1.19	0.2775
Depth*WellPosition	D		2	94	2.63	0.0773
Depth*WellPosition	S		2	94	0.64	0.5293

Example Code for overall analysis among different monitoring blocks

```
options ls=85 nodate nocenter formdlm="+";

data one;
  infile "CREP_Stats.csv"
  firstobs=4 dlm="," dsd;
  input SampleID $ Date : mmdyy10. Block Transect $ WellPosition Depth $
  NO3 Cl NCl DOC lnNO3 lnCl lnNCl lnDOC;
  week=week(date);
run;
```

```

    data sorttime;
    set one;
    run;
proc sort data=sorttime;
by block SampleID Date;
run;

proc mixed data=sorttime COVTEST;
class SampleID depth wellposition transect week block date ;
model lnno3=block|wellposition depth / outp=two;
random transect transect*wellposition week;
lsmeans Block|wellposition/slice=(block wellposition) cl diff;
run;

```

SAS output for NO3-N Concentration Analysis

The SAS System

23

The Mixed Procedure

Model Information

Data Set	WORK.SORTTIME
Dependent Variable	lnNO3
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
SampleID	51	Jav1-a1d Jav1-a1s Jav1-a2s Jav1-a3s Jav1-b1d Jav1-b1s Jav1-b2s Jav1-b3d Jav1-b3s Jav1-c1d Jav1-c1s Jav1-c2d Jav1-c2s Jav1-c3d Jav1-c3s Jav2-a1d Jav2-a1s Jav2-a2d Jav2-a2s Jav2-a3d Jav2-a3s Jav2-b1d Jav2-b1s Jav2-b2d Jav2-b2s Jav2-b3d Jav2-b3s Jav2-c1d Jav2-c1s Jav2-c2d Jav2-c2s Jav2-c3d Jav2-c3s Jav3-a1d Jav3-a1s Jav3-a2d Jav3-a2s Jav3-a3d Jav3-a3s Jav3-b1d Jav3-b1s Jav3-b2d Jav3-b2s Jav3-b3d Jav3-b3s Jav3-c1d Jav3-c1s Jav3-c2d Jav3-c2s Jav3-c3d Jav3-c3s
Depth	2	D S
WellPosition	3	1 2 3
Transect	3	A B C
week	40	2 3 4 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30 31 32 33 34 37 38 39 42 43 46 47 48 50 51
Block	3	1 2 3

+++++

The SAS System

24

The Mixed Procedure

Class Level Information

Class	Levels	Values
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644 16658 16671 16708 16736 16771 16813 16841 16869 16904 16933 16960 17023 17064 17092 17126 17155 17190 17218 17246 17257 17287 17318 17348 17398 17426 17463 17494 17617 17644 17665 17693 17721 17750 17799 17827 17855 17883 17920 17945 17980 18008 18045 18077 18099 18127 18155 18190 18218 18246 18281 18311 18337 18374 18400

Dimensions

Covariance Parameters	4
Columns in X	18
Columns in Z	52
Subjects	1
Max Obs Per Subject	3186

Number of Observations

Number of Observations Read	3186
Number of Observations Used	3037
Number of Observations Not Used	149

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	10530.19470561	
1	5	9777.65997125	0.00002272
2	1	9777.60902561	0.00000025
3	1	9777.60849955	0.00000000

Convergence criteria met.

+++++

The SAS System

25

The Mixed Procedure

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
Transect	0.4464	0.5076	0.88	0.1896
WellPositio*Transect	0.1740	0.1259	1.38	0.0834
week	0.01947	0.009571	2.03	0.0210
Residual	1.4266	0.03696	38.60	<.0001

Fit Statistics

-2 Res Log Likelihood	9777.6
AIC (smaller is better)	9785.6
AICC (smaller is better)	9785.6
BIC (smaller is better)	9782.0

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Block	2	2982	30.71	<.0001
WellPosition	2	4	21.23	0.0074
WellPosition*Block	4	2982	177.46	<.0001
Depth	1	2982	94.74	<.0001

Least Squares Means

Effect	Well Position	Block	Estimate	Standard Error	DF	t Value	Pr > t
Block		1	0.6728	0.4128	2982	1.63	0.1032
Block		2	0.2431	0.4123	2982	0.59	0.5555
Block		3	0.4033	0.4124	2982	0.98	0.3282
WellPosition	1		1.6523	0.4571	4	3.62	0.0225

Least Squares Means

Effect	Well Position	Block	Alpha	Lower	Upper
Block		1	0.05	-0.1365	1.4821
Block		2	0.05	-0.5653	1.0515
Block		3	0.05	-0.4054	1.2119
WellPosition	1		0.05	0.3833	2.9213

+++++

The SAS System

26

The Mixed Procedure

Least Squares Means

Effect	Well Position	Block	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition	2		0.2330	0.4570	4	0.51	0.6370
WellPosition	3		-0.5662	0.4568	4	-1.24	0.2829
WellPosition*Block	1	1	2.1473	0.4608	2982	4.66	<.0001
WellPosition*Block	1	2	1.3988	0.4599	2982	3.04	0.0024

WellPosition*Block	1	3	1.4108	0.4604	2982	3.06	0.0022
WellPosition*Block	2	1	1.3151	0.4618	2982	2.85	0.0044
WellPosition*Block	2	2	-0.6199	0.4596	2982	-1.35	0.1776
WellPosition*Block	2	3	0.003766	0.4597	2982	0.01	0.9935
WellPosition*Block	3	1	-1.4440	0.4602	2982	-3.14	0.0017
WellPosition*Block	3	2	-0.04973	0.4593	2982	-0.11	0.9138
WellPosition*Block	3	3	-0.2048	0.4596	2982	-0.45	0.6559

Least Squares Means

Effect	Well Position	Block	Alpha	Lower	Upper
WellPosition	2		0.05	-1.0358	1.5018
WellPosition	3		0.05	-1.8345	0.7021
WellPosition*Block	1	1	0.05	1.2439	3.0508
WellPosition*Block	1	2	0.05	0.4970	2.3006
WellPosition*Block	1	3	0.05	0.5081	2.3135
WellPosition*Block	2	1	0.05	0.4096	2.2206
WellPosition*Block	2	2	0.05	-1.5211	0.2813
WellPosition*Block	2	3	0.05	-0.8976	0.9052
WellPosition*Block	3	1	0.05	-2.3464	-0.5417
WellPosition*Block	3	2	0.05	-0.9502	0.8508
WellPosition*Block	3	3	0.05	-1.1059	0.6964

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	Estimate	Standard Error	DF
Block		1		2	0.4297	0.05495	2982
Block		1		3	0.2695	0.05574	2982
Block		2		3	-0.1602	0.05171	2982
WellPosition	1		2		1.4193	0.3451	4
WellPosition	1		3		2.2185	0.3448	4
WellPosition	2		3		0.7992	0.3447	4
WellPosition*Block	1	1	1	2	0.7486	0.09501	2982
WellPosition*Block	1	1	1	3	0.7365	0.09714	2982
WellPosition*Block	1	1	2	1	0.8322	0.3565	2982
WellPosition*Block	1	1	2	2	2.7672	0.3533	2982

+++++

The SAS System

27

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	Estimate	Standard Error	DF
WellPosition*Block	1	1	2	3	2.1436	0.3534	2982
WellPosition*Block	1	1	3	1	3.5914	0.3542	2982
WellPosition*Block	1	1	3	2	2.1971	0.3529	2982
WellPosition*Block	1	1	3	3	2.3521	0.3532	2982
WellPosition*Block	1	2	1	3	-0.01203	0.09328	2982
WellPosition*Block	1	2	2	1	0.08368	0.3553	2982
WellPosition*Block	1	2	2	2	2.0186	0.3522	2982
WellPosition*Block	1	2	2	3	1.3950	0.3523	2982
WellPosition*Block	1	2	3	1	2.8428	0.3531	2982
WellPosition*Block	1	2	3	2	1.4485	0.3518	2982

WellPosition*Block	1	2	3	3	1.6036	0.3522	2982
WellPosition*Block	1	3	2	1	0.09571	0.3559	2982
WellPosition*Block	1	3	2	2	2.0307	0.3528	2982
WellPosition*Block	1	3	2	3	1.4070	0.3529	2982
WellPosition*Block	1	3	3	1	2.8548	0.3537	2982
WellPosition*Block	1	3	3	2	1.4605	0.3524	2982
WellPosition*Block	1	3	3	3	1.6156	0.3527	2982
WellPosition*Block	2	1	2	2	1.9350	0.1005	2982
WellPosition*Block	2	1	2	3	1.3113	0.1000	2982
WellPosition*Block	2	1	3	1	2.7591	0.3554	2982
WellPosition*Block	2	1	3	2	1.3648	0.3543	2982
WellPosition*Block	2	1	3	3	1.5199	0.3548	2982
WellPosition*Block	2	2	2	3	-0.6236	0.08875	2982
WellPosition*Block	2	2	3	1	0.8242	0.3527	2982
WellPosition*Block	2	2	3	2	-0.5701	0.3514	2982
WellPosition*Block	2	2	3	3	-0.4151	0.3518	2982
WellPosition*Block	2	3	3	1	1.4478	0.3528	2982
WellPosition*Block	2	3	3	2	0.05349	0.3515	2982
WellPosition*Block	2	3	3	3	0.2086	0.3519	2982
WellPosition*Block	3	1	3	2	-1.3943	0.08954	2982
WellPosition*Block	3	1	3	3	-1.2392	0.09156	2982
WellPosition*Block	3	2	3	3	0.1551	0.08640	2982

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	t Value	Pr > t	Alpha
Block		1		2	7.82	<.0001	0.05
Block		1		3	4.84	<.0001	0.05
Block		2		3	-3.10	0.0020	0.05
WellPosition	1		2		4.11	0.0147	0.05
WellPosition	1		3		6.43	0.0030	0.05
WellPosition	2		3		2.32	0.0813	0.05
WellPosition*Block	1	1	1	2	7.88	<.0001	0.05

+++++

The SAS System

28

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	t Value	Pr > t	Alpha
WellPosition*Block	1	1	1	3	7.58	<.0001	0.05
WellPosition*Block	1	1	2	1	2.33	0.0196	0.05
WellPosition*Block	1	1	2	2	7.83	<.0001	0.05
WellPosition*Block	1	1	2	3	6.07	<.0001	0.05
WellPosition*Block	1	1	3	1	10.14	<.0001	0.05
WellPosition*Block	1	1	3	2	6.23	<.0001	0.05
WellPosition*Block	1	1	3	3	6.66	<.0001	0.05
WellPosition*Block	1	2	1	3	-0.13	0.8974	0.05
WellPosition*Block	1	2	2	1	0.24	0.8138	0.05
WellPosition*Block	1	2	2	2	5.73	<.0001	0.05
WellPosition*Block	1	2	2	3	3.96	<.0001	0.05
WellPosition*Block	1	2	3	1	8.05	<.0001	0.05
WellPosition*Block	1	2	3	2	4.12	<.0001	0.05
WellPosition*Block	1	2	3	3	4.55	<.0001	0.05
WellPosition*Block	1	3	2	1	0.27	0.7880	0.05
WellPosition*Block	1	3	2	2	5.76	<.0001	0.05

WellPosition*Block	1	3	2	3	3.99	<.0001	0.05
WellPosition*Block	1	3	3	1	8.07	<.0001	0.05
WellPosition*Block	1	3	3	2	4.14	<.0001	0.05
WellPosition*Block	1	3	3	3	4.58	<.0001	0.05
WellPosition*Block	2	1	2	2	19.26	<.0001	0.05
WellPosition*Block	2	1	2	3	13.11	<.0001	0.05
WellPosition*Block	2	1	3	1	7.76	<.0001	0.05
WellPosition*Block	2	1	3	2	3.85	0.0001	0.05
WellPosition*Block	2	1	3	3	4.28	<.0001	0.05
WellPosition*Block	2	2	2	3	-7.03	<.0001	0.05
WellPosition*Block	2	2	3	1	2.34	0.0195	0.05
WellPosition*Block	2	2	3	2	-1.62	0.1048	0.05
WellPosition*Block	2	2	3	3	-1.18	0.2382	0.05
WellPosition*Block	2	3	3	1	4.10	<.0001	0.05
WellPosition*Block	2	3	3	2	0.15	0.8791	0.05
WellPosition*Block	2	3	3	3	0.59	0.5535	0.05
WellPosition*Block	3	1	3	2	-15.57	<.0001	0.05
WellPosition*Block	3	1	3	3	-13.53	<.0001	0.05
WellPosition*Block	3	2	3	3	1.79	0.0728	0.05

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	Lower	Upper
Block		1		2	0.3220	0.5375
Block		1		3	0.1603	0.3788
Block		2		3	-0.2616	-0.05881
WellPosition	1		2		0.4612	2.3774

+++++

The SAS System

29

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	Lower	Upper
WellPosition	1		3		1.2612	3.1758
WellPosition	2		3		-0.1579	1.7563
WellPosition*Block	1	1	1	2	0.5623	0.9348
WellPosition*Block	1	1	1	3	0.5461	0.9270
WellPosition*Block	1	1	2	1	0.1333	1.5312
WellPosition*Block	1	1	2	2	2.0745	3.4598
WellPosition*Block	1	1	2	3	1.4507	2.8364
WellPosition*Block	1	1	3	1	2.8968	4.2859
WellPosition*Block	1	1	3	2	1.5052	2.8890
WellPosition*Block	1	1	3	3	1.6595	3.0447
WellPosition*Block	1	2	1	3	-0.1949	0.1709
WellPosition*Block	1	2	2	1	-0.6130	0.7804
WellPosition*Block	1	2	2	2	1.3281	2.7092
WellPosition*Block	1	2	2	3	0.7042	2.0858
WellPosition*Block	1	2	3	1	2.1505	3.5351
WellPosition*Block	1	2	3	2	0.7587	2.1383
WellPosition*Block	1	2	3	3	0.9131	2.2941
WellPosition*Block	1	3	2	1	-0.6021	0.7935
WellPosition*Block	1	3	2	2	1.3389	2.7224
WellPosition*Block	1	3	2	3	0.7151	2.0990
WellPosition*Block	1	3	3	1	2.1613	3.5483
WellPosition*Block	1	3	3	2	0.7696	2.1515

WellPosition*Block	1	3	3	3	0.9240	2.3072
WellPosition*Block	2	1	2	2	1.7380	2.1319
WellPosition*Block	2	1	2	3	1.1152	1.5075
WellPosition*Block	2	1	3	1	2.0623	3.4559
WellPosition*Block	2	1	3	2	0.6701	2.0596
WellPosition*Block	2	1	3	3	0.8242	2.2156
WellPosition*Block	2	2	2	3	-0.7977	-0.4496
WellPosition*Block	2	2	3	1	0.1326	1.5157
WellPosition*Block	2	2	3	2	-1.2592	0.1189
WellPosition*Block	2	2	3	3	-1.1049	0.2747
WellPosition*Block	2	3	3	1	0.7560	2.1396
WellPosition*Block	2	3	3	2	-0.6358	0.7428
WellPosition*Block	2	3	3	3	-0.4815	0.8986
WellPosition*Block	3	1	3	2	-1.5699	-1.2187
WellPosition*Block	3	1	3	3	-1.4188	-1.0597
WellPosition*Block	3	2	3	3	-0.01435	0.3245

+++++

The SAS System 30

The Mixed Procedure

Tests of Effect Slices

Effect	Well Position	Block	Num DF	Den DF	F Value	Pr > F
WellPosition*Block		1	2	2982	56.38	<.0001
WellPosition*Block		2	2	2982	17.46	<.0001
WellPosition*Block		3	2	2982	12.39	<.0001
WellPosition*Block	1		2	2982	39.14	<.0001
WellPosition*Block	2		2	2982	187.07	<.0001
WellPosition*Block	3		2	2982	139.35	<.0001

SAS Output for Cl- Concentration Analysis

The SAS System 31

The Mixed Procedure

Model Information

Data Set	WORK.SORTTIME
Dependent Variable	lnCl
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
SampleID	51	Jav1-a1d Jav1-a1s Jav1-a2s Jav1-a3s Jav1-b1d Jav1-b1s Jav1-b2s Jav1-b3d Jav1-b3s

```

Jav1-c1d Jav1-c1s Jav1-c2d
Jav1-c2s Jav1-c3d Jav1-c3s
Jav2-a1d Jav2-a1s Jav2-a2d
Jav2-a2s Jav2-a3d Jav2-a3s
Jav2-b1d Jav2-b1s Jav2-b2d
Jav2-b2s Jav2-b3d Jav2-b3s
Jav2-c1d Jav2-c1s Jav2-c2d
Jav2-c2s Jav2-c3d Jav2-c3s
Jav3-a1d Jav3-a1s Jav3-a2d
Jav3-a2s Jav3-a3d Jav3-a3s
Jav3-b1d Jav3-b1s Jav3-b2d
Jav3-b2s Jav3-b3d Jav3-b3s
Jav3-c1d Jav3-c1s Jav3-c2d
Jav3-c2s Jav3-c3d Jav3-c3s
Depth                2      D S
WellPosition         3      1 2 3
Transect             3      A B C
week                 40     2 3 4 6 7 8 10 11 12 13 14 15
                    16 17 18 19 20 21 22 23 24 26
                    27 28 29 30 31 32 33 34 37 38
                    39 42 43 46 47 48 50 51
Block                3      1 2 3

```

+++++

The SAS System 32

The Mixed Procedure

Class Level Information

Class	Levels	Values
Date	69	16448 16462 16476 16490 16505 16518 16532 16546 16561 16574 16589 16602 16616 16630 16644 16658 16671 16708 16736 16771 16813 16841 16869 16904 16933 16960 17023 17064 17092 17126 17155 17190 17218 17246 17257 17287 17318 17348 17398 17426 17463 17494 17617 17644 17665 17693 17721 17750 17799 17827 17855 17883 17920 17945 17980 18008 18045 18077 18099 18127 18155 18190 18218 18246 18281 18311 18337 18374 18400

Dimensions

Covariance Parameters	4
Columns in X	18
Columns in Z	52
Subjects	1
Max Obs Per Subject	3186

Number of Observations

Number of Observations Read	3186
Number of Observations Used	2763
Number of Observations Not Used	423

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	6035.74897576	
1	2	5629.04060339	0.00000032
2	1	5629.04051301	0.00000000

Convergence criteria met.

+++++

The SAS System 33

The Mixed Procedure

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error	Z Value	Pr Z
Transect	0.02349	0.03200	0.73	0.2315
WellPositio*Transect	0.02259	0.01701	1.33	0.0921
week	0.06013	0.01571	3.83	<.0001
Residual	0.4263	0.01158	36.81	<.0001

Fit Statistics

-2 Res Log Likelihood	5629.0
AIC (smaller is better)	5637.0
AICC (smaller is better)	5637.1
BIC (smaller is better)	5633.4

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Block	2	2710	54.78	<.0001
WellPosition	2	4	28.75	0.0042
WellPosition*Block	4	2710	17.26	<.0001
Depth	1	2710	22.70	<.0001

Least Squares Means

Effect	Well Position	Block	Estimate	Standard Error	DF	t Value	Pr > t
Block		1	1.8625	0.1119	2710	16.65	<.0001
Block		2	1.5374	0.1113	2710	13.82	<.0001
Block		3	1.7263	0.1114	2710	15.49	<.0001
WellPosition	1		2.1799	0.1323	4	16.48	<.0001

Least Squares Means

Effect	Well Position	Block	Alpha	Lower	Upper
--------	---------------	-------	-------	-------	-------

Block		1	0.05	1.6432	2.0819
Block		2	0.05	1.3192	1.7556
Block		3	0.05	1.5077	1.9448
WellPosition	1		0.05	1.8126	2.5472

+++++

The SAS System

34

The Mixed Procedure

Least Squares Means

Effect	Well Position	Block	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition	2		1.7253	0.1322	4	13.05	0.0002
WellPosition	3		1.2210	0.1319	4	9.26	0.0008
WellPosition*Block	1	1	2.2510	0.1366	2710	16.48	<.0001
WellPosition*Block	1	2	2.1647	0.1355	2710	15.98	<.0001
WellPosition*Block	1	3	2.1241	0.1360	2710	15.62	<.0001
WellPosition*Block	2	1	2.0487	0.1376	2710	14.89	<.0001
WellPosition*Block	2	2	1.3917	0.1351	2710	10.30	<.0001
WellPosition*Block	2	3	1.7355	0.1352	2710	12.83	<.0001
WellPosition*Block	3	1	1.2879	0.1358	2710	9.49	<.0001
WellPosition*Block	3	2	1.0558	0.1347	2710	7.84	<.0001
WellPosition*Block	3	3	1.3192	0.1350	2710	9.77	<.0001

Least Squares Means

Effect	Well Position	Block	Alpha	Lower	Upper
WellPosition	2		0.05	1.3584	2.0923
WellPosition	3		0.05	0.8547	1.5872
WellPosition*Block	1	1	0.05	1.9831	2.5189
WellPosition*Block	1	2	0.05	1.8991	2.4304
WellPosition*Block	1	3	0.05	1.8573	2.3908
WellPosition*Block	2	1	0.05	1.7790	2.3185
WellPosition*Block	2	2	0.05	1.1268	1.6566
WellPosition*Block	2	3	0.05	1.4704	2.0007
WellPosition*Block	3	1	0.05	1.0217	1.5541
WellPosition*Block	3	2	0.05	0.7917	1.3199
WellPosition*Block	3	3	0.05	1.0544	1.5840

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	Estimate	Standard Error	DF
Block		1		2	0.3251	0.03160	2710
Block		1		3	0.1363	0.03208	2710
Block		2		3	-0.1888	0.02961	2710
WellPosition	1		2		0.4546	0.1268	4
WellPosition	1		3		0.9590	0.1265	4
WellPosition	2		3		0.5044	0.1264	4
WellPosition*Block	1	1	1	2	0.08624	0.05502	2710
WellPosition*Block	1	1	1	3	0.1269	0.05628	2710
WellPosition*Block	1	1	2	1	0.2022	0.1370	2710
WellPosition*Block	1	1	2	2	0.8592	0.1342	2710

+++++

The SAS System

35

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	Estimate	Standard Error	DF
WellPosition*Block	1	1	2	3	0.5154	0.1343	2710
WellPosition*Block	1	1	3	1	0.9631	0.1351	2710
WellPosition*Block	1	1	3	2	1.1952	0.1338	2710
WellPosition*Block	1	1	3	3	0.9318	0.1341	2710
WellPosition*Block	1	2	1	3	0.04067	0.05361	2710
WellPosition*Block	1	2	2	1	0.1160	0.1358	2710
WellPosition*Block	1	2	2	2	0.7730	0.1330	2710
WellPosition*Block	1	2	2	3	0.4292	0.1331	2710
WellPosition*Block	1	2	3	1	0.8768	0.1339	2710
WellPosition*Block	1	2	3	2	1.1089	0.1327	2710
WellPosition*Block	1	2	3	3	0.8455	0.1330	2710
WellPosition*Block	1	3	2	1	0.07532	0.1363	2710
WellPosition*Block	1	3	2	2	0.7323	0.1336	2710
WellPosition*Block	1	3	2	3	0.3885	0.1337	2710
WellPosition*Block	1	3	3	1	0.8362	0.1344	2710
WellPosition*Block	1	3	3	2	1.0683	0.1332	2710
WellPosition*Block	1	3	3	3	0.8049	0.1335	2710
WellPosition*Block	2	1	2	2	0.6570	0.05766	2710
WellPosition*Block	2	1	2	3	0.3132	0.05743	2710
WellPosition*Block	2	1	3	1	0.7608	0.1358	2710
WellPosition*Block	2	1	3	2	0.9929	0.1349	2710
WellPosition*Block	2	1	3	3	0.7296	0.1353	2710
WellPosition*Block	2	2	2	3	-0.3438	0.05077	2710
WellPosition*Block	2	2	3	1	0.1038	0.1335	2710
WellPosition*Block	2	2	3	2	0.3359	0.1323	2710
WellPosition*Block	2	2	3	3	0.07254	0.1326	2710
WellPosition*Block	2	3	3	1	0.4476	0.1336	2710
WellPosition*Block	2	3	3	2	0.6797	0.1324	2710
WellPosition*Block	2	3	3	3	0.4163	0.1327	2710
WellPosition*Block	3	1	3	2	0.2321	0.05122	2710
WellPosition*Block	3	1	3	3	-0.03129	0.05237	2710
WellPosition*Block	3	2	3	3	-0.2634	0.04925	2710

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	t Value	Pr > t	Alpha
Block		1		2	10.29	<.0001	0.05
Block		1		3	4.25	<.0001	0.05
Block		2		3	-6.38	<.0001	0.05
WellPosition	1		2		3.59	0.0231	0.05
WellPosition	1		3		7.58	0.0016	0.05
WellPosition	2		3		3.99	0.0163	0.05
WellPosition*Block	1	1	1	2	1.57	0.1171	0.05

+++++

The SAS System

36

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	t Value	Pr > t	Alpha
WellPosition*Block	1	1	1	3	2.25	0.0242	0.05
WellPosition*Block	1	1	2	1	1.48	0.1402	0.05
WellPosition*Block	1	1	2	2	6.40	<.0001	0.05
WellPosition*Block	1	1	2	3	3.84	0.0001	0.05
WellPosition*Block	1	1	3	1	7.13	<.0001	0.05
WellPosition*Block	1	1	3	2	8.93	<.0001	0.05
WellPosition*Block	1	1	3	3	6.95	<.0001	0.05
WellPosition*Block	1	2	1	3	0.76	0.4481	0.05
WellPosition*Block	1	2	2	1	0.85	0.3932	0.05
WellPosition*Block	1	2	2	2	5.81	<.0001	0.05
WellPosition*Block	1	2	2	3	3.22	0.0013	0.05
WellPosition*Block	1	2	3	1	6.55	<.0001	0.05
WellPosition*Block	1	2	3	2	8.36	<.0001	0.05
WellPosition*Block	1	2	3	3	6.36	<.0001	0.05
WellPosition*Block	1	3	2	1	0.55	0.5807	0.05
WellPosition*Block	1	3	2	2	5.48	<.0001	0.05
WellPosition*Block	1	3	2	3	2.91	0.0037	0.05
WellPosition*Block	1	3	3	1	6.22	<.0001	0.05
WellPosition*Block	1	3	3	2	8.02	<.0001	0.05
WellPosition*Block	1	3	3	3	6.03	<.0001	0.05
WellPosition*Block	2	1	2	2	11.39	<.0001	0.05
WellPosition*Block	2	1	2	3	5.45	<.0001	0.05
WellPosition*Block	2	1	3	1	5.60	<.0001	0.05
WellPosition*Block	2	1	3	2	7.36	<.0001	0.05
WellPosition*Block	2	1	3	3	5.39	<.0001	0.05
WellPosition*Block	2	2	2	3	-6.77	<.0001	0.05
WellPosition*Block	2	2	3	1	0.78	0.4367	0.05
WellPosition*Block	2	2	3	2	2.54	0.0112	0.05
WellPosition*Block	2	2	3	3	0.55	0.5844	0.05
WellPosition*Block	2	3	3	1	3.35	0.0008	0.05
WellPosition*Block	2	3	3	2	5.13	<.0001	0.05
WellPosition*Block	2	3	3	3	3.14	0.0017	0.05
WellPosition*Block	3	1	3	2	4.53	<.0001	0.05
WellPosition*Block	3	1	3	3	-0.60	0.5503	0.05
WellPosition*Block	3	2	3	3	-5.35	<.0001	0.05

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	Lower	Upper
Block		1		2	0.2631	0.3871
Block		1		3	0.07337	0.1992
Block		2		3	-0.2469	-0.1308
WellPosition	1		2		0.1025	0.8066

+++++

The SAS System 37

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	_Well Position	_Block	Lower	Upper
WellPosition	1		3		0.6076	1.3103

WellPosition	2		3		0.1534	0.8554
WellPosition*Block	1	1	1	2	-0.02164	0.1941
WellPosition*Block	1	1	1	3	0.01654	0.2373
WellPosition*Block	1	1	2	1	-0.06650	0.4709
WellPosition*Block	1	1	2	2	0.5962	1.1223
WellPosition*Block	1	1	2	3	0.2522	0.7787
WellPosition*Block	1	1	3	1	0.6982	1.2279
WellPosition*Block	1	1	3	2	0.9328	1.4576
WellPosition*Block	1	1	3	3	0.6688	1.1947
WellPosition*Block	1	2	1	3	-0.06445	0.1458
WellPosition*Block	1	2	2	1	-0.1503	0.3823
WellPosition*Block	1	2	2	2	0.5121	1.0339
WellPosition*Block	1	2	2	3	0.1681	0.6903
WellPosition*Block	1	2	3	1	0.6143	1.1393
WellPosition*Block	1	2	3	2	0.8488	1.3691
WellPosition*Block	1	2	3	3	0.5848	1.1063
WellPosition*Block	1	3	2	1	-0.1920	0.3427
WellPosition*Block	1	3	2	2	0.4704	0.9942
WellPosition*Block	1	3	2	3	0.1264	0.6506
WellPosition*Block	1	3	3	1	0.5726	1.0997
WellPosition*Block	1	3	3	2	0.8071	1.3295
WellPosition*Block	1	3	3	3	0.5431	1.0666
WellPosition*Block	2	1	2	2	0.5440	0.7701
WellPosition*Block	2	1	2	3	0.2006	0.4258
WellPosition*Block	2	1	3	1	0.4946	1.0271
WellPosition*Block	2	1	3	2	0.7285	1.2574
WellPosition*Block	2	1	3	3	0.4643	0.9948
WellPosition*Block	2	2	2	3	-0.4434	-0.2442
WellPosition*Block	2	2	3	1	-0.1579	0.3655
WellPosition*Block	2	2	3	2	0.07655	0.5953
WellPosition*Block	2	2	3	3	-0.1875	0.3326
WellPosition*Block	2	3	3	1	0.1857	0.7096
WellPosition*Block	2	3	3	2	0.4201	0.9394
WellPosition*Block	2	3	3	3	0.1561	0.6766
WellPosition*Block	3	1	3	2	0.1317	0.3325
WellPosition*Block	3	1	3	3	-0.1340	0.07140
WellPosition*Block	3	2	3	3	-0.3600	-0.1668

+++++

The SAS System 38

The Mixed Procedure

Tests of Effect Slices

Effect	Well Position	Block	Num DF	Den DF	F Value	Pr > F
WellPosition*Block		1	2	2710	28.38	<.0001
WellPosition*Block		2	2	2710	36.64	<.0001
WellPosition*Block		3	2	2710	18.19	<.0001
WellPosition*Block	1		2	2710	2.63	0.0721
WellPosition*Block	2		2	2710	66.72	<.0001
WellPosition*Block	3		2	2710	17.05	<.0001

SAS Output for Overall DOC Concentration Analysis

The SAS System 39

The Mixed Procedure

Model Information

```
Data Set                WORK.SORTTIME
Dependent Variable      lnDOC
Covariance Structure    Variance Components
Estimation Method       REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment
```

Class Level Information

```
Class      Levels  Values
SampleID   51      Jav1-a1d Jav1-a1s Jav1-a2s
           Jav1-a3s Jav1-b1d Jav1-b1s
           Jav1-b2s Jav1-b3d Jav1-b3s
           Jav1-c1d Jav1-c1s Jav1-c2d
           Jav1-c2s Jav1-c3d Jav1-c3s
           Jav2-a1d Jav2-a1s Jav2-a2d
           Jav2-a2s Jav2-a3d Jav2-a3s
           Jav2-b1d Jav2-b1s Jav2-b2d
           Jav2-b2s Jav2-b3d Jav2-b3s
           Jav2-c1d Jav2-c1s Jav2-c2d
           Jav2-c2s Jav2-c3d Jav2-c3s
           Jav3-a1d Jav3-a1s Jav3-a2d
           Jav3-a2s Jav3-a3d Jav3-a3s
           Jav3-b1d Jav3-b1s Jav3-b2d
           Jav3-b2s Jav3-b3d Jav3-b3s
           Jav3-c1d Jav3-c1s Jav3-c2d
           Jav3-c2s Jav3-c3d Jav3-c3s
Depth      2      D S
WellPosition 3      1 2 3
Transect    3      A B C
week        40     2 3 4 6 7 8 10 11 12 13 14 15
           16 17 18 19 20 21 22 23 24 26
           27 28 29 30 31 32 33 34 37 38
           39 42 43 46 47 48 50 51
Block      3      1 2 3
```

+++++

The SAS System 40

The Mixed Procedure

Class Level Information

```
Class      Levels  Values
Date       69      16448 16462 16476 16490 16505
           16518 16532 16546 16561 16574
           16589 16602 16616 16630 16644
           16658 16671 16708 16736 16771
           16813 16841 16869 16904 16933
           16960 17023 17064 17092 17126
           17155 17190 17218 17246 17257
           17287 17318 17348 17398 17426
           17463 17494 17617 17644 17665
           17693 17721 17750 17799 17827
           17855 17883 17920 17945 17980
```

18008 18045 18077 18099 18127
 18155 18190 18218 18246 18281
 18311 18337 18374 18400

Dimensions

Covariance Parameters 4
 Columns in X 18
 Columns in Z 52
 Subjects 1
 Max Obs Per Subject 3186

Number of Observations

Number of Observations Read 3186
 Number of Observations Used 320
 Number of Observations Not Used 2866

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	938.12863264	
1	4	701.83551775	0.00073127
2	1	701.78199360	0.00002556
3	1	701.78026487	0.00000004
4	1	701.78026244	0.00000000

Convergence criteria met.

+++++

The SAS System 41

The Mixed Procedure

Covariance Parameter Estimates

Cov Parm	Estimate	Standard Error	Z Value	Pr Z
Transect	0	.	.	.
WellPositio*Transect	0	.	.	.
week	0.7561	0.3886	1.95	0.0258
Residual	0.4524	0.03695	12.24	<.0001

Fit Statistics

-2 Res Log Likelihood 701.8
 AIC (smaller is better) 705.8
 AICC (smaller is better) 705.8
 BIC (smaller is better) 704.0

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
--------	--------	--------	---------	--------

Block	2	294	4.48	0.0122
WellPosition	2	4	2.92	0.1655
WellPosition*Block	4	294	2.43	0.0482
Depth	1	294	6.71	0.0100

Least Squares Means

Effect	Well Position	Block	Estimate	Standard Error	DF	t Value	Pr > t
Block		1	1.0133	0.2832	294	3.58	0.0004
Block		2	0.7466	0.2857	294	2.61	0.0094
Block		3	0.7563	0.2862	294	2.64	0.0087
WellPosition	1		0.8272	0.2847	4	2.91	0.0439

Least Squares Means

Effect	Well Position	Block	Alpha	Lower	Upper
Block		1	0.05	0.4559	1.5707
Block		2	0.05	0.1843	1.3090
Block		3	0.05	0.1931	1.3196
WellPosition	1		0.05	0.03673	1.6177

+++++

The SAS System

42

The Mixed Procedure

Least Squares Means

Effect	Well Position	Block	Estimate	Standard Error	DF	t Value	Pr > t
WellPosition	2		0.9522	0.2856	4	3.33	0.0290
WellPosition	3		0.7368	0.2852	4	2.58	0.0611
WellPosition*Block	1	1	0.9700	0.3036	294	3.20	0.0015
WellPosition*Block	1	2	0.9458	0.3032	294	3.12	0.0020
WellPosition*Block	1	3	0.5658	0.3040	294	1.86	0.0637
WellPosition*Block	2	1	1.1989	0.3042	294	3.94	0.0001
WellPosition*Block	2	2	0.7391	0.2974	294	2.49	0.0135
WellPosition*Block	2	3	0.9187	0.2979	294	3.08	0.0022
WellPosition*Block	3	1	0.8709	0.2995	294	2.91	0.0039
WellPosition*Block	3	2	0.5550	0.2973	294	1.87	0.0629
WellPosition*Block	3	3	0.7844	0.2984	294	2.63	0.0090

Least Squares Means

Effect	Well Position	Block	Alpha	Lower	Upper
WellPosition	2		0.05	0.1594	1.7451
WellPosition	3		0.05	-0.05499	1.5286
WellPosition*Block	1	1	0.05	0.3726	1.5674
WellPosition*Block	1	2	0.05	0.3491	1.5425
WellPosition*Block	1	3	0.05	-0.03248	1.1641
WellPosition*Block	2	1	0.05	0.6001	1.7976
WellPosition*Block	2	2	0.05	0.1538	1.3244
WellPosition*Block	2	3	0.05	0.3324	1.5051

WellPosition*Block	3	1	0.05	0.2815	1.4603
WellPosition*Block	3	2	0.05	-0.03011	1.1401
WellPosition*Block	3	3	0.05	0.1971	1.3718

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	Estimate	Standard Error	DF
Block		1		2	0.2666	0.09842	294
Block		1		3	0.2569	0.09848	294
Block		2		3	-0.00968	0.09005	294
WellPosition	1		2		-0.1250	0.1011	4
WellPosition	1		3		0.09044	0.09876	4
WellPosition	2		3		0.2155	0.08933	4
WellPosition*Block	1	1	1	2	0.02416	0.1895	294
WellPosition*Block	1	1	1	3	0.4042	0.1898	294
WellPosition*Block	1	1	2	1	-0.2289	0.1966	294
WellPosition*Block	1	1	2	2	0.2309	0.1829	294

+++++

The SAS System

43

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	Estimate	Standard Error	DF
WellPosition*Block	1	1	2	3	0.05127	0.1826	294
WellPosition*Block	1	1	3	1	0.09907	0.1876	294
WellPosition*Block	1	1	3	2	0.4150	0.1830	294
WellPosition*Block	1	1	3	3	0.1856	0.1829	294
WellPosition*Block	1	2	1	3	0.3800	0.1675	294
WellPosition*Block	1	2	2	1	-0.2530	0.1740	294
WellPosition*Block	1	2	2	2	0.2067	0.1577	294
WellPosition*Block	1	2	2	3	0.02711	0.1585	294
WellPosition*Block	1	2	3	1	0.07491	0.1638	294
WellPosition*Block	1	2	3	2	0.3908	0.1577	294
WellPosition*Block	1	2	3	3	0.1614	0.1588	294
WellPosition*Block	1	3	2	1	-0.6330	0.1749	294
WellPosition*Block	1	3	2	2	-0.1733	0.1601	294
WellPosition*Block	1	3	2	3	-0.3529	0.1599	294
WellPosition*Block	1	3	3	1	-0.3051	0.1647	294
WellPosition*Block	1	3	3	2	0.01085	0.1597	294
WellPosition*Block	1	3	3	3	-0.2186	0.1601	294
WellPosition*Block	2	1	2	2	0.4597	0.1632	294
WellPosition*Block	2	1	2	3	0.2801	0.1639	294
WellPosition*Block	2	1	3	1	0.3279	0.1657	294
WellPosition*Block	2	1	3	2	0.6439	0.1628	294
WellPosition*Block	2	1	3	3	0.4144	0.1649	294
WellPosition*Block	2	2	2	3	-0.1796	0.1484	294
WellPosition*Block	2	2	3	1	-0.1318	0.1535	294
WellPosition*Block	2	2	3	2	0.1841	0.1473	294
WellPosition*Block	2	2	3	3	-0.04530	0.1495	294
WellPosition*Block	2	3	3	1	0.04780	0.1540	294
WellPosition*Block	2	3	3	2	0.3637	0.1481	294
WellPosition*Block	2	3	3	3	0.1343	0.1498	294
WellPosition*Block	3	1	3	2	0.3159	0.1528	294
WellPosition*Block	3	1	3	3	0.08650	0.1546	294

WellPosition*Block 3 2 3 3 -0.2294 0.1491 294

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	t Value	Pr > t	Alpha
Block		1		2	2.71	0.0071	0.05
Block		1		3	2.61	0.0095	0.05
Block		2		3	-0.11	0.9145	0.05
WellPosition	1		2		-1.24	0.2839	0.05
WellPosition	1		3		0.92	0.4116	0.05
WellPosition	2		3		2.41	0.0734	0.05
WellPosition*Block	1	1	1	2	0.13	0.8986	0.05

+++++

The SAS System

44

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	t Value	Pr > t	Alpha
WellPosition*Block	1	1	1	3	2.13	0.0340	0.05
WellPosition*Block	1	1	2	1	-1.16	0.2454	0.05
WellPosition*Block	1	1	2	2	1.26	0.2077	0.05
WellPosition*Block	1	1	2	3	0.28	0.7791	0.05
WellPosition*Block	1	1	3	1	0.53	0.5978	0.05
WellPosition*Block	1	1	3	2	2.27	0.0240	0.05
WellPosition*Block	1	1	3	3	1.01	0.3112	0.05
WellPosition*Block	1	2	1	3	2.27	0.0240	0.05
WellPosition*Block	1	2	2	1	-1.45	0.1469	0.05
WellPosition*Block	1	2	2	2	1.31	0.1910	0.05
WellPosition*Block	1	2	2	3	0.17	0.8643	0.05
WellPosition*Block	1	2	3	1	0.46	0.6477	0.05
WellPosition*Block	1	2	3	2	2.48	0.0138	0.05
WellPosition*Block	1	2	3	3	1.02	0.3102	0.05
WellPosition*Block	1	3	2	1	-3.62	0.0003	0.05
WellPosition*Block	1	3	2	2	-1.08	0.2800	0.05
WellPosition*Block	1	3	2	3	-2.21	0.0281	0.05
WellPosition*Block	1	3	3	1	-1.85	0.0649	0.05
WellPosition*Block	1	3	3	2	0.07	0.9459	0.05
WellPosition*Block	1	3	3	3	-1.37	0.1731	0.05
WellPosition*Block	2	1	2	2	2.82	0.0052	0.05
WellPosition*Block	2	1	2	3	1.71	0.0885	0.05
WellPosition*Block	2	1	3	1	1.98	0.0487	0.05
WellPosition*Block	2	1	3	2	3.96	<.0001	0.05
WellPosition*Block	2	1	3	3	2.51	0.0125	0.05
WellPosition*Block	2	2	2	3	-1.21	0.2271	0.05
WellPosition*Block	2	2	3	1	-0.86	0.3912	0.05
WellPosition*Block	2	2	3	2	1.25	0.2124	0.05
WellPosition*Block	2	2	3	3	-0.30	0.7621	0.05
WellPosition*Block	2	3	3	1	0.31	0.7565	0.05
WellPosition*Block	2	3	3	2	2.46	0.0146	0.05
WellPosition*Block	2	3	3	3	0.90	0.3707	0.05
WellPosition*Block	3	1	3	2	2.07	0.0396	0.05
WellPosition*Block	3	1	3	3	0.56	0.5763	0.05
WellPosition*Block	3	2	3	3	-1.54	0.1250	0.05

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	Lower	Upper
Block		1		2	0.07291	0.4603
Block		1		3	0.06312	0.4507
Block		2		3	-0.1869	0.1675
WellPosition	1		2		-0.4057	0.1557

+++++

The SAS System

45

The Mixed Procedure

Differences of Least Squares Means

Effect	Well Position	Block	Well Position	_Block	Lower	Upper
WellPosition	1		3		-0.1838	0.3646
WellPosition	2		3		-0.03258	0.4635
WellPosition*Block	1	1	1	2	-0.3488	0.3971
WellPosition*Block	1	1	1	3	0.03067	0.7776
WellPosition*Block	1	1	2	1	-0.6158	0.1581
WellPosition*Block	1	1	2	2	-0.1290	0.5907
WellPosition*Block	1	1	2	3	-0.3081	0.4106
WellPosition*Block	1	1	3	1	-0.2701	0.4682
WellPosition*Block	1	1	3	2	0.05492	0.7751
WellPosition*Block	1	1	3	3	-0.1744	0.5456
WellPosition*Block	1	2	1	3	0.05039	0.7096
WellPosition*Block	1	2	2	1	-0.5954	0.08934
WellPosition*Block	1	2	2	2	-0.1037	0.5171
WellPosition*Block	1	2	2	3	-0.2848	0.3391
WellPosition*Block	1	2	3	1	-0.2474	0.3972
WellPosition*Block	1	2	3	2	0.08044	0.7012
WellPosition*Block	1	2	3	3	-0.1511	0.4739
WellPosition*Block	1	3	2	1	-0.9772	-0.2889
WellPosition*Block	1	3	2	2	-0.4884	0.1418
WellPosition*Block	1	3	2	3	-0.6676	-0.03822
WellPosition*Block	1	3	3	1	-0.6291	0.01895
WellPosition*Block	1	3	3	2	-0.3035	0.3251
WellPosition*Block	1	3	3	3	-0.5336	0.09640
WellPosition*Block	2	1	2	2	0.1386	0.7809
WellPosition*Block	2	1	2	3	-0.04246	0.6027
WellPosition*Block	2	1	3	1	0.001921	0.6540
WellPosition*Block	2	1	3	2	0.3235	0.9642
WellPosition*Block	2	1	3	3	0.08992	0.7389
WellPosition*Block	2	2	2	3	-0.4716	0.1124
WellPosition*Block	2	2	3	1	-0.4339	0.1703
WellPosition*Block	2	2	3	2	-0.1059	0.4741
WellPosition*Block	2	2	3	3	-0.3395	0.2489
WellPosition*Block	2	3	3	1	-0.2553	0.3509
WellPosition*Block	2	3	3	2	0.07230	0.6552
WellPosition*Block	2	3	3	3	-0.1605	0.4291
WellPosition*Block	3	1	3	2	0.01519	0.6167
WellPosition*Block	3	1	3	3	-0.2178	0.3908
WellPosition*Block	3	2	3	3	-0.5230	0.06410

+++++

The Mixed Procedure

Tests of Effect Slices

Effect	Well Position	Block	Num DF	Den DF	F Value	Pr > F
WellPosition*Block		1	2	294	1.99	0.1383
WellPosition*Block		2	2	294	3.08	0.0476
WellPosition*Block		3	2	294	2.45	0.0883
WellPosition*Block	1		2	294	3.36	0.0360
WellPosition*Block	2		2	294	3.97	0.0199
WellPosition*Block	3		2	294	2.34	0.0985

Appendix G: Stream Concentrations

Introduction

One of the major goals of riparian buffers enrolled in the CREP program is to reduce $\text{NO}_3\text{-N}$ concentrations in the surface water body that the buffer surrounds. At a basin-wide scale, water quality contributions from individual buffers could add-up to significant improvements in water quality. The stream running through the site, Ruth's Branch, was where a majority of the groundwater discharged and ultimately left the site. The stream was sampled for $\text{NO}_3\text{-N}$ concentrations throughout the monitoring period in order to help assess any changes in the buffer removal.

Materials and Methods

Three stream sampling locations were positioned in the buffer. The first was located upstream of all of the monitoring blocks, that is upstream from Block 3. This location was referred to as the upper stream. The next location was positioned between Block 2 and Block 3 near the middle of the buffer and was referred to as the mid-stream location. The last sampling location was located downstream of all the monitoring blocks, that is downstream of Block 1. This location was the outlet for all water that flowed through the monitoring blocks and was referred to as the lower stream location.

Each location was equipped with a 6712 Portable Teledyne ISCO automated sampler (Teledyne ISCO, Lincoln NE). Samplers were set to take flow-weighted NO₃-N samples at each location which were collected and analyzed every two weeks.

Results

Figure 123 shows a bar graph of the mean NO₃-N concentration at each sampling location throughout the monitoring period. The upper stream location usually has the lowest concentration, although in a few years the concentration was slightly higher than the mean concentration found at the mid stream location. The lower stream location has the highest mean concentration in NO₃-N throughout the monitoring period. This indicated that the stream was receiving NO₃-N concentrations from groundwater that was flowing through the buffer. Mean NO₃-N concentrations increased 327% between the upper stream location and lower stream location. The figure also shows that concentrations throughout the stream were slightly higher during years with high rainfall, such as 2006 and 2009.

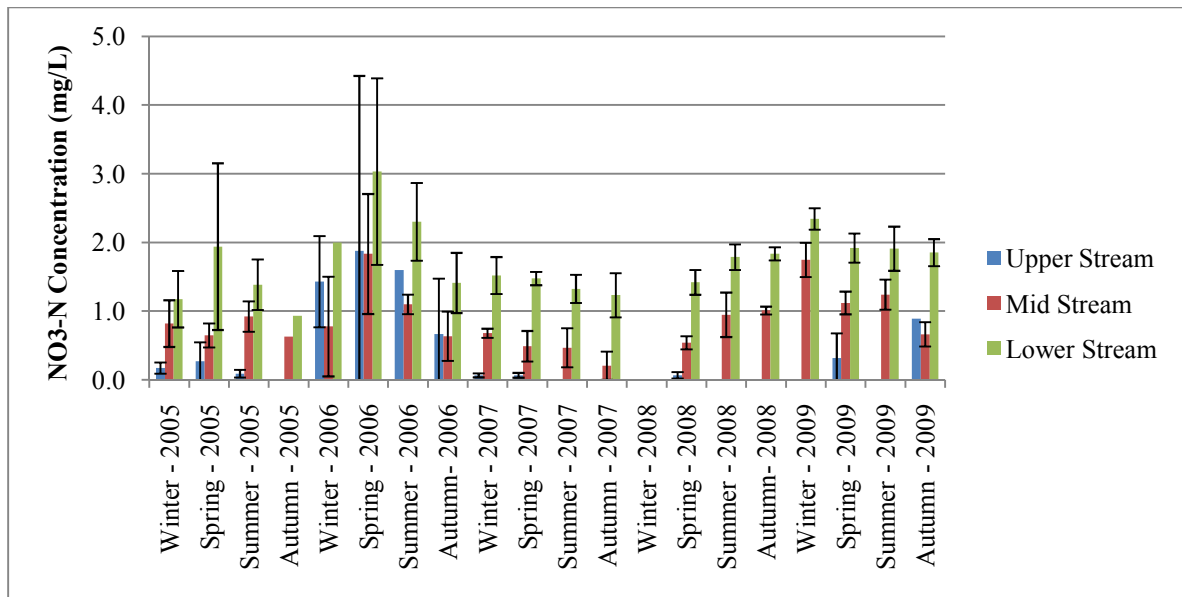


Figure 122. Mean stream NO₃-N concentrations from the upper, middle, and lower parts of the site. Error bars represent the standard deviation of each mean. No samples were collected in the winter of 2008.

Appendix H: Well Water Quality Data

Block 1, Transect A, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-als	1/12/2005	0.26	0.05	7.10	0.37	0.77						
Jav1-als	1/26/2005	0.05	0.05	14.10	0.13	0.11						
Jav1-als	2/9/2005	0.21	0.1	19.70	0.6	1.4						
Jav1-als	2/23/2005	0.07	0.05	28.80	0.15	0.67						
Jav1-als	3/10/2005	0.25	0.05	40.40	0.53	1.3						
Jav1-als	3/23/2005	0.005	0.05	11.40	0.1	0.7						
Jav1-als	4/6/2005	0.005	0.05	0.05	0.04	0.68	1.6	3.7	0.01			
Jav1-als	4/20/2005	0.005	0.66	12.10	0.08	1.2	1.1	5.4	2.24			
Jav1-als	5/5/2005	0.005	0.05	11.00	0.04	0.58	1.1	2.5	4.40			
Jav1-als	5/18/2005	0.005	0.05	12.10	0.06	0.75	0.5	6.5	1.86			
Jav1-als	6/2/2005	0.005	0.05	18.50	0.05	0.54	2.7	18.2	1.02			
Jav1-als	6/15/2005	0.005	0.05	16.90	2	4.2	0.5	10.2	1.66			
Jav1-als	12/1/2005	1.4	0.25	7.70			4	10.5	0.73			
Jav1-als	1/12/2006	0.005	0.21	114.80			6.4	126	0.91			
Jav1-als	2/9/2006	0.005	0.22	112.10			13.1	108	1.04			
Jav1-als	3/9/2006	0.005	0.05	45.40			5	76.5	0.59			
Jav1-als	6/8/2006	0.005	0.2	18.90			4	22.5	0.84			
Jav1-als	8/10/2006	0.13	0.43	12.70			4	15	0.85			
JAV1-A1S	9/20/2006	0.11	0.05	4.60			3.4	4.1	1.12			
JAV1-A1S	10/18/2006	0.02	0.05	2.50			2.8	2.3	1.09			
JAV1-A1S	11/21/2006	0.16	0.05	21.90			4.5	26.5	0.83			
JAV1-A1S	12/20/2006	0.25	0.05	25.50			4.3	15.8	1.61			
JAV1-A1S	1/24/2007	0.08	0.05	19.10			2.6	13.8	1.38			
JAV1-A1S	2/21/2007	0.17	0.05	15.10			3.8	9.1	1.66			
JAV1-A1S	4/1/07	0.19	1.3	6.10			11.3	7.3	0.84			
JAV1-A1S	4/22/2008	0.13	0.03	9.47			8.92	4.82	1.96			
JAV1-A1S	5/13/2008	0.07	0.06	12.80			6.1	5.02	2.55			
JAV1-A1S	6/10/2008	0.12	0.24	9.76			9.69	9.89	0.99			
JAV1-A1S	7/8/2008		0.44	6.90				4.18	1.65			
JAV1-A1S	12/17/2008		0	16.65				2.65	6.28			
JAV1-A1S	1/23/2009		0.04	20.76				27.56	0.75			
JAV1A1S	3/24/2009			17.92				8.98	2.00	7.46	20.3	
JAV1A1S	4/21/2009			51.73				39.12	1.32	19.34	48.1	4.84
JAV1A1S	11/17/2009			14.81				10.59	1.40			
JAV1A1S	12/15/2009			14.31				10.25	1.40	4.43	10.2	12.37
JAV1A1S	1/19/2010			12.4				5.75	2.16	4.31	13.2	
JAV1A1S	3/16/2010			11.94				4.88	2.45	2.8	2.26	
JAV1A1S	4/22/2010			10.73				5.56	1.93	2.96	3.29	

Block 1, Transect A, Well Position 1(Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-ald	1/12/2005	0.1	0.13	0.41	0.12	0.83						
Jav1-ald	1/26/2005	0.02	0.13	0.37	0.04	0.45						
Jav1-ald	2/9/2005	0.21	0.25	1.1	1.5	3.6						
Jav1-ald	2/23/2005	0.06	0.17	1.6	0.21	1						
Jav1-ald	3/10/2005	0.06	0.05	2.3	0.1	0.57						
Jav1-ald	3/23/2005	0.005	0.05	4.2	0.13	0.49						
Jav1-ald	4/20/2005	0.005	0.05	2.4	0.07	0.91	1.3	12.2	0.20			
Jav1-ald	5/5/2005	0.005	0.05	1.8	0.09	0.65	1.6	5.9	0.31			
Jav1-ald	4/6/2005	0.005	0.05	2.7	0.08	1	1.4	12.2	0.22			
Jav1-ald	5/18/2005	0.005	0.05	2.2	0.09	0.58	1.3	12.6	0.17			
Jav1-ald	6/2/2005	0.005	0.05	2.6	0.2	0.95	3.4	13.2	0.20			
Jav1-ald	6/15/2005	0.005	0.05	3.1	0.12	0.78	1.1	10.4	0.30			
Jav1-ald	6/29/2005	0.005	0.05	2.1	0.12	0.67	0.5	10.7	0.20			
Jav1-ald	7/13/2005	0.005	0.05	1.4	0.08	0.46	1	11.2	0.13			
Jav1-ald	7/27/2005	0.005	0.05	1.2			2.3	14.1	0.09			
Jav1-ald	8/10/2005	0.005	0.05	0.97			1.8	12.7	0.08			
Jav1-ald	8/23/2005	0.01	0.05	0.97			1.4	13.3	0.07			
Jav1-ald	9/29/2005	0.04	0.76	1.2			2.2	13.4	0.09			
Jav1-ald	10/27/2005	0.01	0.46	0.68			1.4	12.7	0.05			
Jav1-ald	12/1/2005	0.01	0.14	6.4			2.1	10.5	0.61			
Jav1-ald	1/12/2006	0.005	0.05	4.3			1.1	12.8	0.34			
Jav1-ald	2/9/2006	0.005	0.05	11.8			2.7	25.1	0.47			
Jav1-ald	3/9/2006	0.005	0.05	14.4			2.2	28	0.51			
Jav1-ald	4/13/2006	0.02	0.05	12.3			1.5	25.7	0.48			
Jav1-ald	5/12/2006	0.005	0.05	8.5			1.9	20.7	0.41			
Jav1-ald	6/8/2006	0.02	0.12	7.3			2.3	20.9	0.35			
Jav1-ald	8/10/2006	0.1	0.05	8.3			3.1	16.1	0.52			
JAV1-A1D	9/20/2006	0.06	0.05	3.7			2.8	13.7	0.27			
JAV1-A1D	10/18/2006	0.07	0.05	2.9			2.7	12.1	0.24			
JAV1-A1D	11/21/2006	0.02	0.05	4.9			3.5	11	0.45			
JAV1-A1D	12/20/2006	0.08	0.05	5.3			3.7	12.6	0.42			
JAV1-A1D	1/24/2007	0.02	0.05	5.2			2.3	14.5	0.36			
JAV1-A1D	2/21/2007	0.05	0.05	5			2.8	10.4	0.48			
JAV1-A1D	3/21/2007	0.04	0.05	4.8			2.1	11	0.44			
JAV1-A1D	4/1/2007	0.06	0.05	4.5			2.3	11	0.41			
JAV1-A1D	5/1/2007	0.08	0.16	3.5			2.2	10	0.35			
JAV1-A1D	6/1/2007	0.06	0.1	2.9			1.9	8.8	0.33			
JAV1-A1D	7/1/2007	0.18	0.67	1.8			3.1	10.6	0.17			
JAV1-A1D	8/20/2007	0.12	0.05	1.8			2.3	10.9	0.17			
JAV1-A1D	9/17/2007	0.1	0.16	1.2			2.2	12.3	0.10			
JAV1-A1D	11/24/2007	0.03	0.05	31			2.5	11.5	2.70			

JAV1-A1D	4/22/2008	0.21	0.05	17.82	11.37	86.67	0.21					
JAV1-A1D	5/13/2008	0.12	0.16	17.82	5.68	10.43	1.71					
JAV1-A1D	6/10/2008	0.13	0.03	14.09	9.27	10.91	1.29					
JAV1-A1D	7/8/2008		0.094	13.03		7.98	1.63					
JAV1A1D	8/6/2008		0.29	11.03		10.21	1.08				18.49	
JAV1-A1D	9/24/2008		0.183	11.21		8.82	1.27					
JAV1-A1D	10/22/2008		0.03	13.50								
JAV1-A1D	11/19/2008		0.038	10.3		7.88	1.31				5.51	
JAV1-A1D	12/17/2008		0	19.12		5.84	3.27					
JAV1-A1D	1/23/2009		0.03	16.43		9.17	1.79					
JAV1A1D	2/17/2009		0.01	16.25		10.19	1.59				2.46	
JAV1A1D	3/24/2009			16.43		11.67	1.41	13.71	13.4			
JAV1A1D	4/21/2009			14.96		11.03	1.36	14.14	14.3	4.25		
JAV1A1D	5/28/2009			21.51		17.36	1.24	17.8	12.6			
JAV1A1D	6/29/2009		0.18	28.69		16.95	1.69	20.16	15.9	10.3		
JAV1A1D	7/21/2009			31.36		16.59	1.89	24	20.5			
JAV1A1D	8/18/2009			29.73		13.98	2.13	20.1	1.44	10.78		
JAV1A1D	9/15/2009			20.06		11.56	1.74	15.18	3.6			
JAV1A1D	10/20/2009		0.03	19.08		9.04	2.11	14.4	1.76	11.33		
JAV1A1D	11/17/2009			1.85		11.2	0.17	6	20			
JAV1A1D	12/15/2009			19		8.64	2.20	14.07	5.9	16.1		
JAV1A1D	1/19/2010			17.23		9.28	1.86	13.74	14.1			
JAV1A1D	2/18/2010		0.03	16.35		9.24	1.77	14	12.4	10.04		
JAV1A1D	3/16/2010			15.61		8.87	1.76	14.1	2.7			
JAV1A1D	4/22/2010			13.19		8.58	1.54	13.54	3.16			
JAV1A1D	5/18/2010			13.18		8.04	1.64	12.44	0			

Block 1, Transect A, Well Position 2 (mid-buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-a2s	1/12/2005	0.02	0.05	0.05	0.09	0.54						
Jav1-a2s	1/26/2005	0.005	0.05	0.9	0.16	0.63						
Jav1-a2s	2/9/2005	0.005	0.05	0.86	0.1	0.93						
Jav1-a2s	2/23/2005	0.01	0.05	0.83	0.02	0.53						
Jav1-a2s	3/10/2005	0.01	0.05	1.4	0.04	0.75						
Jav1-a2s	3/23/2005	0.01	0.05	3.9	0.04	0.45						
Jav1-a2s	4/6/2005	0.005	0.05	4.1	0.04	0.55	1.5	3.2	1.28			
Jav1-a2s	4/20/2005	0.01	0.05	2.9	0.04	0.43	1.6	4.5	0.64			
Jav1-a2s	5/5/2005	0.005	0.05	2.7	0.02	0.76	1.4	2.8	0.96			
Jav1-a2s	5/18/2005	0.005	0.05	2.7	0.03	0.54	1.6	4.3	0.63			
Jav1-a2s	6/2/2005	0.005	0.05	3.5	0.1	0.78	3	4.6	0.76			
Jav1-a2s	6/15/2005	0.005	0.05	3.7	0.06	0.54	1.2	3.2	1.16			
Jav1-a2s	6/29/2005	0.005	0.05	5.5	0.04	0.76	1.1	3.2	1.72			

Jav1-a2s	7/13/2005	0.005	0.05	4.8	0.005	0.21	0.5	3.5	1.37										
Jav1-a2s	7/27/2005	0.005	0.11	4.7			1.7	6.2	0.76										
Jav1-a2s	8/10/2005	0.005	0.05	3.6			1.1	5.3	0.68										
Jav1-a2s	8/23/2005	0.005	0.05	4.3			1.2	5.8	0.74										
Jav1-a2s	12/1/2005	0.005	0.13	0.79			1.5	4.2	0.19										
Jav1-a2s	1/12/2006	0.005	0.05	1.6			1.4	3.6	0.44										
Jav1-a2s	2/9/2006	0.005	0.05	1.4			1.9	4.8	0.29										
Jav1-a2s	3/9/2006	0.005	0.05	0.76			1.2	9.8	0.08										
Jav1-a2s	4/13/2006	0.005	0.05	0.57			3	7.7	0.07										
Jav1-a2s	5/12/2006	0.005	0.05	0.15			1.5	6.9	0.02										
Jav1-a2s	6/8/2006	0.005	0.05	0.28			1.5	8.8	0.03										
Jav1-a2s	8/10/2006	0.02	0.14	0.72			2.7	13.4	0.05										
JAV1-A2S	9/20/2006	0.01	0.05	0.24			1.9	9.7	0.02										
JAV1-A2S	10/18/2006	0.01	0.05	0.26			3.1	12	0.02										
JAV1-A2S	11/21/2006	0.005	0.05	0.93			2	8.1	0.11										
JAV1-A2S	12/20/2006	0.005	0.05	1.6			2.3	6.6	0.24										
JAV1-A2S	1/24/2007	0.005	0.05	5.1			1.7	9.2	0.55										
JAV1-A2S	2/21/2007	0.005	0.05	7			2	7.1	0.99										
JAV1-A2S	3/21/2007	0.005	0.05	7.2			0.5	8.2	0.88										
JAV1-A2S	4/1/2007	0.005	0.05	6.7			1.8	7.6	0.88										
JAV1-A2S	5/1/2007	0.01	0.05	5.9			2	6.5	0.91										
JAV1-A2S	6/1/2007	0.02	0.05	5.7			2.2	6.4	0.89										
JAV1-A2S	7/1/2007	0.02	0.05	5.6			1.9	7	0.80										
JAV1-A2S	11/24/2007	0.02	0.05	5.5			2.9	5.6	0.98										
JAV1-A2S	4/22/2008	0.06	0.01	1.47			6	10.07	0.15										
JAV1-A2S	5/13/2008	0.06	0.02	1.21			7.01	7.81	0.15										
JAV1-A2S	6/10/2008	0.07	0.07	1.35			5.84	8.9	0.15										
JAV1-A2S	7/8/2008		0.012	0.53				5.85	0.09										
JAV1A2S	8/6/2008		0.16	0.41				8.56	0.05									15.12	
JAV1-A2S	9/24/2008		0.016	0.12				9.71	0.01										
JAV1-A2S	11/19/2008		0.021	0.45				8.37	0.05										
JAV1-A2S	12/17/2008		0	0.34				7.26	0.05										
JAV1-A2S	1/23/2009		0.01	0.78				10.67	0.07										
JAV1A2S	2/17/2009		0	0.61				8.41	0.07									0.95	
JAV1A2S	3/24/2009			0.67				9.9	0.07										
JAV1A2S	4/21/2009			0.6				7.88	0.08									1.03	
JAV1A2S	5/28/2009			0.69				8.46	0.08										
JAV1A2S	6/29/2009		0.02	0.46				8	0.06	3.4	4.6							3.22	
JAV1A2S	7/21/2009			0.44				8.96	0.05										
JAV1A2S	11/17/2009			0.89				11	0.08										
JAV1A2S	12/15/2009			4.46				10.82	0.41									9.31	
JAV1A2S	1/19/2010			5.71				8.89	0.64										
JAV1A2S	2/18/2010		0.02	5.87				7.99	0.73									3.08	
JAV1A2S	3/16/2010			6.19				7.18	0.86										
JAV1A2S	4/22/2010			3.62				6.85	0.53										

JAV1A2S 5/18/2010

3.59

7.24 0.50

Block 1, Transect A, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-a3s	1/12/2005	0.04	0.18	0.05	0.11	1.9						
Jav1-a3s	1/26/2005	0.02	0.11	0.05	0.14	0.8						
Jav1-a3s	2/9/2005	0.01	0.18	0.05	0.27	1.8						
Jav1-a3s	2/23/2005	0.02	0.15	0.05	0.07	1						
Jav1-a3s	3/10/2005	0.005	0.11	0.49	0.05	0.8						
Jav1-a3s	3/23/2005	0.005	0.32	19.2	0.09	0.77						
Jav1-a3s	4/20/2005	0.005	0.14	0.05	0.05	0.72	4.6	3.5	0.01			
Jav1-a3s	4/6/2005	0.005	0.05	0.05	0.03	0.65	4.7	4.1	0.01			
Jav1-a3s	5/18/2005	0.005	0.05	0.05	0.03	0.54	3.9	1.8	0.03			
Jav1-a3s	6/2/2005	0.04	0.05	0.25	1.5	9.4	6.8	4.9	0.05			
Jav1-a3s	6/15/2005	0.01	0.05	0.14	0.8	7.7	4	2	0.07			
Jav1-a3s	6/29/2005	0.06	0.05	0.28	1.1	7.8	4.5	4.9	0.06			
Jav1-a3s	7/13/2005	0.03	0.05	0.52	0.73	4.4	3.1	3.7	0.14			
Jav1-a3s	7/27/2005	0.03	0.05	1.1			6.2	9.9	0.11			
Jav1-a3s	8/10/2005	0.005	0.05	0.34			3.7	4.8	0.07			
Jav1-a3s	8/23/2005	0.02	0.05	0.49			3.1	5	0.10			
Jav1-a3s	9/29/2005	0.02	0.05	0.59			3.3	4.8	0.12			
Jav1-a3s	10/27/2005	0.02	0.05	0.53			2.3	5.1	0.10			
Jav1-a3s	12/1/2005	0.01	0.12	0.29			2.7	2.9	0.10			
Jav1-a3s	1/12/2006	0.005	0.38	0.12			3.1	3.2	0.04			
Jav1-a3s	2/9/2006	0.005	0.05	0.05			5.6	4.3	0.01			
Jav1-a3s	3/9/2006	0.02	0.12	0.05			6.2	5.2	0.01			
Jav1-a3s	4/13/2006	0.01	0.26	0.05			5.9	3.6	0.01			
Jav1-a3s	5/12/2006	0.005	0.05	0.05			3.1	1.8	0.03			
Jav1-a3s	6/8/2006	0.02	0.23	0.05			0.5	2.5	0.02			
Jav1-a3s	8/10/2006	0.04	0.31	0.24			4.5	3.6	0.07			
JAV1-A3S	9/20/2006	0.02	0.17	0.05			4.7	1.2	0.04			
JAV1-A3S	10/18/2006	0.01	0.05	0.05			4.4	0.5	0.10			
JAV1-A3S	11/21/2006	1.4	0.61	0.05			47	4.4	0.01			
JAV1-A3S	12/20/2006	0.005	0.05	0.05			3.9	2.4	0.02			
JAV1-A3S	1/24/2007	0.005	0.05	0.05			3	5.4	0.01			
JAV1-A3S	2/21/2007	0.005	0.05	0.05			4.8	4.2	0.01			
JAV1-A3S	3/21/2007	0.005	0.05	0.11			2.1	4.7	0.02			
JAV1-A3S	Apr-07	0.005	0.05	0.05			3.3	4.6	0.01			
JAV1-A3S	May-07	0.02	0.11	0.05			3.6	3.9	0.01			
JAV1-A3S	Jun-07	0.02	0.23	0.05			3.2	3	0.02			
JAV1-A3S	Jul-07	0.06	0.36	0.05			3.5	2.2	0.02			
JAV1-A3S	Aug-07	0.02	0.45	0.05			3.2	2	0.03			
JAV1-A3S	Nov-07	0.21	0.05	0.22			7.4	0.5				
JAV1-A3S	5/13/2008	0.06	0.04	0.01			6.06	5.07	0.00			
JAV1-A3S	7/8/2008		0.085	0.09				1.88	0.05			

JAV1A3S	8/6/2008	0.1	0.05				3.92	0.01				16.74
JAV1-A3S	9/24/2008	0.088	0.06				4.06	0.01				
JAV1-A3S	11/19/2008	0.022	0.07				3.09	0.02				
JAV1-A3S	12/17/2008	0	0				2.25	0.00				
JAV1-A3S	1/23/2009	0.03	0				6.9	0.00				
JAV1A3S	2/17/2009	0.01	0				9.13	0.00	4.8	8.7	1.5	
JAV1A3S	3/24/2009		0.08				5.65	0.01	4.41	10.8		
JAV1A3S	4/21/2009		0				5.81	0.00	4.09	9.1	2.15	
JAV1A3S	5/28/2009		0.06				5.42	0.01	5.2	7.8		
JAV1A3S	9/15/2009		0.08				3.32	0.02				
JAV1A3S	11/17/2009		0.08				2.78	0.03	6.5	10.7		
JAV1A3S	12/15/2009		0				6.02	0.00	5.19	2.5	6.92	
JAV1A3S	1/19/2010		0.06				8.04	0.01	4.26	9.9		
JAV1A3S	2/18/2010	0.02	0.09				5.81	0.02	3.42	7.2	4.6	
JAV1A3S	3/16/2010		0.04				5.94	0.01	3.6	2.28		
JAV1A3S	4/22/2010		0				5.78	0.00	3.49	2.11		
JAV1A3S	5/18/2010		0.07				4.84	0.01	4.47	0.44		

Block 1, Transect B, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-b1s	1/12/2005	0.005	0.05	0.05	0.005	0.05						
Jav1-b1s	1/26/2005	0.04	0.05	10.50	0.36	1.2						
Jav1-b1s	2/9/2005	0.06	0.11	7.50	0.28	0.86						
Jav1-b1s	2/23/2005	0.18	0.14	4.70	1.2	5.7						
Jav1-b1s	3/10/2005	0.03	0.05	4.60	0.09	0.85						
Jav1-b1s	3/23/2005	0.005	0.05	2.40	0.11	0.66						
Jav1-b1s	4/6/2005	0.13	0.05	4.80	0.24	1.6	2.3	1.6	3.00			
Jav1-b1s	4/20/2005	0.005	0.05	5.10	0.11	0.83	1.8	5	1.02			
JAV1-B1S	11/21/2006	0.005	0.05	6.10			2.3	10.1	0.60			
JAV1-B1S	12/20/2006	0.17	0.05	26.60			4.5	17.7	1.50			
JAV1-B1S	1/24/2007	0.05	0.05	10.30			3.3	8.2	1.26			
JAV1-B1S	2/21/2007	0.2	0.05	7.10			6	4	1.78			
JAV1-B1S	3/21/2007	0.17	0.05	5.20			3.9	2.9	1.79			
JAV1-B1S	5/13/2008	0.11	0.02	8.98			7.06	4.55	1.97			
JAV1B1S	3/24/2009			33.33				33.12	1.01	12.48	36.2	
JAV1B1S	11/17/2009			7.63				27.39	0.28	7	17.9	
JAV1B1S	12/15/2009			11.31				17.59	0.64	5.49	5.8	14.39
JAV1B1S	1/19/2010			24.89				5.86	4.25	5.69	20.2	
JAV1B1S	2/18/2010		4.76	15.03				2.49	6.04	2.22	8.8	1.9
JAV1B1S	3/16/2010			17.23				3.94	4.37			

Block 1, Transect B, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-b1d	1/12/2005	0.17	0.05	4.6	0.25	0.79						
Jav1-b1d	1/26/2005	0.2	0.24	4.4	0.43	0.35						
Jav1-b1d	2/9/2005	0.21	0.05	4.6	0.27	0.45						
Jav1-b1d	2/23/2005	0.14	0.05	4.7	0.16	0.59						
Jav1-b1d	3/10/2005	0.13	0.05	4.9	0.13	0.43						
Jav1-b1d	3/23/2005	0.005	0.05	5	0.17	0.5						
Jav1-b1d	4/6/2005	0.01	0.05	6.5	0.11	0.64	2.6	5.2	1.25			
Jav1-b1d	4/20/2005	0.11	0.05	5.7	0.16	0.58	1.4	7.4	0.77			
Jav1-b1d	5/5/2005	0.1	0.05	5.7	0.19	0.78	1.2	1.6	3.56			
Jav1-b1d	5/18/2005	0.1	0.05	6.4	0.15	0.82	1.3	7.5	0.85			
Jav1-b1d	6/2/2005	0.11	0.05	6.6	0.14	0.49	2.7	7.6	0.87			
Jav1-b1d	6/15/2005	0.1	0.05	6.4	0.1	0.68	1.1	5.6	1.14			
Jav1-b1d	6/29/2005	0.14	0.05	6.9	0.22	0.56	0.5	5.6	1.23			
Jav1-b1d	7/13/2005	0.19	0.05	7	0.19	0.3	0.5	5.8	1.21			
Jav1-b1d	7/27/2005	0.18	0.05	7.1			1.7	9.9	0.72			
Jav1-b1d	8/10/2005	0.08	0.05	4.9			1.3	6.7	0.73			
Jav1-b1d	8/23/2005	0.13	0.05	5.8			1.3	8	0.73			
Jav1-b1d	9/29/2005	0.29	0.05	6.1			1.5	8.1	0.75			
Jav1-b1d	10/27/2005	0.15	0.05	5.8			0.5	8.3	0.70			
Jav1-b1d	12/1/2005	0.15	0.05	6.4			1.8	5.6	1.14			
Jav1-b1d	1/12/2006	0.13	0.05	7.6			1.4	5.8	1.31			
Jav1-b1d	2/9/2006	0.13	0.05	8.6			2.5	6.6	1.30			
JAV1-b1d	3/9/2006	0.1	0.05	8.4			2.3	6.5	1.29			
Jav1-b1d	4/13/2006	0.13	0.05	7.3			3.5	7.1	1.03			
Jav1-b1d	5/12/2006	0.12	0.05	9.1			0.5	7	1.30			
Jav1-b1d	6/8/2006	0.08	0.32	9.5			1.3	16.9	0.56			
Jav1-b1d	8/10/2006	0.19	0.05	11.7			1.7	15.4	0.76			
JAV1-B1D	9/20/2006	0.24	0.05	11.8			1.4	10	1.18			
JAV1-B1D	10/18/2006	0.14	0.05	12.6			1.3	10.2	1.24			
JAV1-B1D	11/21/2006	0.13	0.05	12.9			1.8	10.3	1.25			
JAV1-B1D	12/20/2006	0.13	0.05	13			1.5	10.8	1.20			
JAV1-B1D	1/24/2007	0.11	0.05	13.3			2	14.6	0.91			
JAV1-B1D	2/21/2007	0.11	0.05	12.5			1.7	11.6	1.08			
JAV1-B1D	3/21/2007	0.1	0.05	13			0.5	13.2	0.98			
JAV1-B1D	Apr-07	0.12	0.05	14.2			1.6	11.7	1.21			
JAV1-B1D	May-07	0.26	0.05	13.7			1.4	11.7	1.17			
JAV1-B1D	Jun-07	1.5	0.1	11.9			3.3	11.1	1.07			
JAV1-B1D	Jul-07	0.95	0.05	11.5			1.8	12.5	0.92			
JAV1-B1D	Aug-07	0.58	0.05	12.6			1.5	12.4	1.02			
JAV1-B1D	Nov-07	0.56	0.05	10.9			1.9	11.2	0.97			
JAV1-B1D	5/13/2008	0.42	0.03	18.37			5.26	13.79	1.33			

JAV1-B1D	6/10/2008	0.39	0.11	12.61		5.75	15.3	0.82				
JAV1-B1D	7/8/2008		0.019	13.74			12.35	1.11				
JAV1B1D	8/6/2008		0.11	12.15			15.93	0.76				17.52
JAV1-B1D	9/24/2008		0.075	10.29			15.29	0.67				
JAV1-B1D	12/17/2008		0	11.83			14.76	0.80				
JAV1-B1D	1/23/2009		0.02	12.21			18.52	0.66				
JAV1B1D	2/17/2009		0	11.7			13.44	0.87	6.2	6.4	1.39	
JAV1B1D	3/24/2009			13.06			13.41	0.97	8.24	23.8		
JAV1B1D	4/21/2009			12.72			12.65	1.01	8.48	22.5	1.33	
JAV1B1D	5/28/2009			13.26			13.3	1.00	9.1	18.1		
JAV1B1D	6/29/2009		0.04	14.15			12.38	1.14	9.3	21.6	2.99	
JAV1B1D	7/21/2009			13.05			14.47	0.90				
JAV1B1D	9/15/2009			8.28			11.93	0.69				
JAV1B1D	11/17/2009			10.07			12.4	0.81	8.8	20.5		
JAV1B1D	12/15/2009			12.09			13.22	0.91	8.75	14.1	8.54	
JAV1B1D	1/19/2010			13.49			12.26	1.10	8.52	20.8		
JAV1B1D	2/18/2010		0.02	14.7			12.91	1.14	6.15	6.5	2.64	
JAV1B1D	3/16/2010			15.8			13.14	1.20	8.4	4.21		
JAV1B1D	4/22/2010			16.51			12.84	1.29	8.1	4.34		
JAV1B1D	5/18/2010			15.9			12.64	1.26	9.33	2.08		

Block 1, Transect B, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-b2s	1/12/2005	0.03	0.05	1.1	0.07	0.48						
Jav1-b2s	1/26/2005	0.02	0.05	1.8	0.15	0.35						
Jav1-b2s	2/9/2005	0.02	0.05	3.1	0.04	0.57						
Jav1-b2s	2/23/2005	0.02	0.05	2.9	0.04	0.64						
Jav1-b2s	3/10/2005	0.01	0.05	5.2	0.02	0.46						
Jav1-b2s	3/23/2005	0.11	0.05	5.7	0.13	0.3						
Jav1-b2s	4/20/2005	0.005	0.05	5.8	0.34	0.7	1.4	9.5	0.61			
Jav1-b2s	5/5/2005	0.01	0.05	3.1	0.1	0.95	2.7	1.5	2.07			
Jav1-b2s	4/6/2005	0.005	0.05	6.8	0.04	0.59	1.3	7.9	0.86			
Jav1-b2s	5/18/2005	0.005	0.05	3.3	0.06	0.43	4	7.2	0.46			
Jav1-b2s	6/2/2005	0.005	0.05	3.2	0.04	0.51	2.4	8.8	0.36			
Jav1-b2s	6/15/2005	0.005	0.05	3.7	0.04	0.47	1.3	6.7	0.55			
Jav1-b2s	6/29/2005	0.01	0.05	6.5	0.02	0.47	1	7.3	0.89			
Jav1-b2s	7/13/2005	0.01	0.05	3.7	0.06	0.34	0.5	7.9	0.47			
Jav1-b2s	7/27/2005	0.005	0.05	3.7			2.2	12	0.31			
Jav1-b2s	8/10/2005	0.005	0.05	2.7			1.2	10.2	0.26			
Jav1-b2s	8/23/2005	0.01	0.05	1.9			1.1	10.1	0.19			
Jav1-b2s	10/27/2005	0.02	0.05	1.2			0.5	10.2	0.12			
Jav1-b2s	12/1/2005	0.02	0.05	2.8			1.7	7.6	0.37			

Jav1-b2s	1/12/2006	0.005	0.05	4.3	2.1	10.2	0.42	
Jav1-b2s	2/9/2006	0.005	0.05	13.2	4.6	55.4	0.24	
Jav1-b2s	3/9/2006	0.005	0.05	21	3.5	48.6	0.43	
Jav1-b2s	4/13/2006	0.005	0.05	27.9	2.7	45.7	0.61	
Jav1-b2s	5/12/2006	0.005	0.11	23.5	3.6	39	0.60	
Jav1-b2s	6/8/2006	0.005	0.05	15.5	2.1	32.1	0.48	
Jav1-b2s	8/10/2006	0.07	0.05	8.2	3.1	19.4	0.42	
JAV1-B2S	9/20/2006	0.04	0.05	4.5	2.7	9.4	0.48	
JAV1-B2S	10/18/2006	0.02	0.05	4.1	2.3	8.4	0.49	
JAV1-B2S	11/21/2006	0.05	0.05	28.5	3.7	15.6	1.83	
JAV1-B2S	12/20/2006	0.005	0.05	14.4	2.1	14	1.03	
JAV1-B2S	1/24/2007	0.005	0.05	14.3	1.7	16.4	0.87	
JAV1-B2S	2/21/2007	0.005	0.05	13.5	2.5	9.9	1.36	
JAV1-B2S	3/21/2007	0.005	0.05	9.3	1.9	9.8	0.95	
JAV1-B2S	4/1/2007	0.01	0.05	5.3	1.7	6.4	0.83	
JAV1-B2S	5/1/2007	0.03	0.11	5.4	2.7	7	0.77	
JAV1-B2S	6/1/2007	0.02	0.05	6.1	1.8	8.9	0.69	
JAV1-B2S	7/1/2007	0.03	0.05	5.4	1.5	11.3	0.48	
JAV1-B2S	8/20/2007	0.06	0.05	5.5	3	11.9	0.46	
JAV1-B2S	9/17/2007	0.1	0.14	4	2.4	11.7	0.34	
JAV1-B2S	11/24/2007	0.03	0.05	9.7	2.7	11.6	0.84	
JAV1-B2S	5/13/2008	0.09	0.02	8.39	5.5	5.19	1.62	
JAV1-B2S	6/10/2008	0.09	0.00	2.79	6.02	5.71	0.49	
JAV1-B2S	7/8/2008		0.028	3.8		5.24	0.73	
JAV1B2S	8/6/2008		0.1	4.8		10.34	0.46	18.6
JAV1-B2S	9/24/2008		0.027	4.54		10.35	0.44	
JAV1-B2S	12/17/2008		0	3.28		11.46	0.29	
JAV1-B2S	1/23/2009		0.03	2.66		15.66	0.17	
JAV1B2S	2/17/2009		0.003	6.93		24.09	0.29	1.9
JAV1B2S	3/24/2009			7.67		24.99	0.31	
JAV1B2S	4/21/2009			19.07		22.86	0.83	2.67
JAV1B2S	5/28/2009			29.12		33.54	0.87	
JAV1B2S	6/29/2009		0.07	24.96		36.05	0.69	
JAV1B2S	7/21/2009			16.23		27.73	0.59	
JAV1B2S	10/20/2009		0.01	12.37		10.4	1.19	3.89
JAV1B2S	11/17/2009			4.39		26.75	0.16	
JAV1B2S	12/15/2009			2.43		16.9	0.14	9.92
JAV1B2S	1/19/2010			6.11		9.05	0.68	
JAV1B2S	3/16/2010			5.68		9.78	0.58	
JAV1B2S	4/22/2010			1.67		8.46	0.20	
JAV1B2S	5/18/2010			9.42		7.07	1.33	

Block 1, Transect B, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-b3s	1/12/2005	0.11	0.05	0.05	0.99	1.8						
Jav1-b3s	1/26/2005	0.09	0.05	0.05	1.1	1.4						
Jav1-b3s	2/9/2005	0.18	0.11	0.05	0.45	0.8						
Jav1-b3s	2/23/2005	0.07	0.05	0.11	0.63	1.3						
Jav1-b3s	3/10/2005	0.04	0.05	0.05	0.23	0.45						
Jav1-b3s	3/23/2005	0.02	0.05	0.2	0.12	0.05						
Jav1-b3s	4/20/2005	0.005	0.05	0.88	0.13	0.65	1.3	4.1	0.21			
Jav1-b3s	4/6/2005	0.005	0.05	1.4	0.21	0.94	4.2	5.5	0.25			
Jav1-b3s	5/18/2005	0.005	0.05	0.05	0.28	0.33	4.5	6.5	0.01			
Jav1-b3s	6/2/2005	0.02	0.05	0.14	1.5	1.3	2.7	3.6	0.04			
Jav1-b3s	6/15/2005	0.005	0.05	0.05	1.5	1.4	1.2	5	0.01			
Jav1-b3s	6/29/2005	0.005	0.05	0.05	0.05	0.39	1.1	5.3	0.01			
Jav1-b3s	7/13/2005	0.005	0.05	0.05	0.16	0.23	1.2	5.3	0.01			
Jav1-b3s	7/27/2005	0.005	0.05	0.54			1.6	8.4	0.06			
Jav1-b3s	8/10/2005	0.005	0.05	0.16			1	7.2	0.02			
Jav1-b3s	8/23/2005	0.01	0.05	0.15			1.5	7.7	0.02			
Jav1-b3s	9/29/2005	0.03	0.05	0.55			1.4	7.4	0.07			
Jav1-b3s	10/27/2005	0.02	0.05	0.17			0.5	6.4	0.03			
Jav1-b3s	12/1/2005	0.01	0.05	0.12			1.7	3.6	0.03			
Jav1-b3s	1/12/2006	0.005	0.05	0.16			2	2.1	0.08			
Jav1-b3s	2/9/2006	0.005	0.05	0.23			1.5	2.8	0.08			
Jav1-b3s	3/9/2006	0.03	0.05	0.05			2.9	3.8	0.01			
Jav1-b3s	4/13/2006	0.01	0.05	0.11			0.5	3.2	0.03			
Jav1-b3s	5/12/2006	0.005	0.05	0.4			0.5	2.4	0.17			
Jav1-b3s	6/8/2006	0.005	0.05	0.05			0.5	5.9	0.01			
Jav1-b3s	8/10/2006	0.04	0.15	0.11			1.6	6.4	0.02			
JAV1-B3S	9/20/2006	0.04	0.05	0.05			1.3	2.9	0.02			
JAV1-B3S	10/18/2006	0.02	0.05	0.05			1.4	2.9	0.02			
JAV1-B3S	11/21/2006	0.01	0.05	0.05			1.4	2.6	0.02			
JAV1-B3S	12/20/2006	0.02	0.05	0.05			1.1	2	0.03			
JAV1-B3S	1/24/2007	0.02	0.05	0.05			1.1	3.1	0.02			
JAV1-B3S	2/21/2007	0.03	0.05	0.05			1.8	1.8	0.03			
JAV1-B3S	3/21/2007	0.02	0.05	0.05			0.5	2.3	0.02			
JAV1-B3S	Apr-07	0.03	0.05	0.05			1.1	2.8	0.02			
JAV1-B3S	May-07	0.04	0.05	0.05			0.5	1.6	0.03			
JAV1-B3S	Jun-07	0.05	0.05	0.14			1.2	2.6	0.05			
JAV1-B3S	Jul-07	0.05	0.05	0.05			1.2	3	0.02			
JAV1-B3S	Aug-07	0.05	0.19	0.05			1.1	3.1	0.02			
JAV1-B3S	Sep-07	0.03	0.05	0.05			0.5	3.7	0.01			
JAV1-B3S	Oct-07	0.05	0.05	0.16			2.2	3				
JAV1-B3S	5/13/2008	0.12	0.02	0.05			4.7	5.13	0.01			

JAV1-B3S	7/8/2008	0.031	0.08			3.68	0.02	13.9	6.5		
JAV1B3S	8/6/2008	0.07	0.14			5.2	0.03				16.37
JAV1-B3S	9/24/2008	0.005	0.12			5.35	0.02				
JAV1-B3S	10/22/2008	0.00	0.07			5.28	0.01				
JAV1-B3S	11/19/2008	0.008	0.09			5.85	0.02				
JAV1-B3S	12/17/2008	0	0			5.03	0.00				
JAV1-B3S	1/23/2009	0.01	0			7.2	0.00				
JAV1B3S	2/17/2009	0	0			5.29	0.00	14.8	5.7		0.79
JAV1B3S	3/24/2009		0.1			4.85	0.02	16.05	7		
JAV1B3S	4/21/2009		0.01			4.28	0.00	16.9	6.5		0.74
JAV1B3S	5/28/2009		0.09			5.09	0.02	17.1	4.2		
JAV1B3S	6/29/2009	0.03	0.09			5.58	0.02				
JAV1B3S	7/21/2009		0.17			5.27	0.03				
JAV1B3S	8/18/2009		0.13			4.97	0.03				
JAV1B3S	9/15/2009		0.12			5.16	0.02	12.83	1.4		
JAV1B3S	10/20/2009	0.01	0.09			5.67	0.02	12.3	0.11		1.46
JAV1B3S	11/17/2009		0.1			5.6	0.02				
JAV1B3S	12/15/2009		0.06			5.58	0.01	15.13	0.66		7.09
JAV1B3S	1/19/2010		0.03			4.81	0.01	15.6	6		
JAV1B3S	2/18/2010	0.02	0.05			4.65	0.01	18.51	6.3		2.69
JAV1B3S	3/16/2010		0.07			4.89	0.01	16	1.69		
JAV1B3S	4/22/2010		0.07			5.12	0.01	15.65	1.63		
JAV1B3S	5/18/2010		0.08			5.05	0.02	16.1	0		

Block 1, Transect B, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-b3d	1/12/2005	0.25	0.05	0.05	1.7	1.6						
Jav1-b3d	1/26/2005	0.16	0.05	0.05	2.1	1.4						
Jav1-b3d	2/9/2005	0.05	0.05	0.05	2.1	1.3						
Jav1-b3d	2/23/2005	0.2	0.11	0.15	3.5	7.1						
Jav1-b3d	3/10/2005	0.09	0.05	0.05	0.81	0.63						
Jav1-b3d	3/23/2005	0.005	0.05	7	0.65	0.43						
Jav1-b3d	4/20/2005	0.02	0.05	0.05	0.43	0.46	2.6	5	0.01			
Jav1-b3d	5/5/2005	0.02	0.11	0.05	0.38	1.6	1.5	1	0.05			
Jav1-b3d	4/6/2005	0.005	0.05	2	0.38	0.69	2.1	0.5	4.00			
Jav1-b3d	5/18/2005	0.005	0.05	0.05	0.61	0.38	2.7	3.1	0.02			
Jav1-b3d	6/2/2005	0.02	0.05	0.05	0.17	0.58	2.3	7.1	0.01			
Jav1-b3d	6/15/2005	0.005	0.05	0.05	1.3	1.2	1.1	2.1	0.02			
Jav1-b3d	6/29/2005	0.02	0.05	0.05	1.2	0.97	1.4	2.4	0.02			
Jav1-b3d	7/13/2005	0.02	0.05	0.3	0.31	0.27	0.5	2.3	0.13			
Jav1-b3d	7/27/2005	0.11	0.05	0.93			2	6.1	0.15			
Jav1-b3d	8/10/2005	0.01	0.05	0.23			1.4	4	0.06			

Jav1-b3d	8/23/2005	0.02	0.05	0.16	1.8	4.3	0.04			
Jav1-b3d	9/29/2005	0.03	0.05	0.2	1.3	4	0.05			
Jav1-b3d	10/27/2005	0.03	0.05	0.26	1.5	4.1	0.06			
Jav1-b3d	12/1/2005	0.02	0.05	0.11	0.5	2.1	0.05			
Jav1-b3d	1/12/2006	0.03	0.05	0.13	1.8	2.7	0.05			
Jav1-b3d	2/9/2006	0.02	0.05	0.13	1.1	2.1	0.06			
Jav1-b3d	3/9/2006	0.09	0.12	0.05	3.3	5.6	0.01			
Jav1-b3d	4/13/2006	0.02	0.05	0.14	0.5	3.2	0.04			
Jav1-b3d	5/12/2006	0.02	0.05	0.05	0.5	2.1	0.02			
Jav1-b3d	6/8/2006	0.005	0.18	0.1	1	5.8	0.02			
Jav1-b3d	8/10/2006	0.07	0.05	0.05	1.4	1.9	0.03			
JAV1-B3D	9/20/2006	0.08	0.05	0.05	1.4	1.1	0.05			
JAV1-B3D	10/18/2006	0.07	0.05	0.05	1.3	0.5	0.10			
JAV1-B3D	11/21/2006	0.07	0.05	0.05	1.7	0.5	0.10			
JAV1-B3D	12/20/2006	0.08	0.05	0.05	1.3	0.5	0.10			
JAV1-B3D	1/24/2007	0.04	0.05	0.05	0.5	1.2	0.04			
JAV1-B3D	2/21/2007	0.05	0.05	0.2	1.2	1.3	0.15			
JAV1-B3D	3/21/2007	0.05	0.05	0.15	4.6	1.1	0.14			
JAV1-B3D	4/1/2007	0.05	0.05	0.15	1.1	1.4	0.11			
JAV1-B3D	5/1/2007	0.07	0.05	0.05	1.7	<1				
JAV1-B3D	6/1/2007	0.06	0.05	0.05	1.2	<1				
JAV1-B3D	7/1/2007	0.07	0.05	0.05	1.5	1.2				
JAV1-B3D	8/20/2007	0.08	0.1	0.05	1.3	1.4				
JAV1-B3D	9/17/2007	0.1	0.05	0.05	1.4	1.8				
JAV1-B3D	10/24/2007	0.1	0.05	0.05	2.6	1.2				
JAV1-B3D	11/24/2007	0.07	0.05	0.17	1.6	1				
JAV1-B3D	5/13/2008	0.2	0.02	0.02	4.36	3.26	0.01			
JAV1-B3D	6/10/2008	0.11	0.00	0.07	5.03	5.65	0.01			
JAV1-B3D	7/8/2008		0.028	0.01		0.84	0.01	6.46	7	
JAV1B3D	8/6/2008		0.02	0.03		2.67	0.01			15.83
JAV1-B3D	9/24/2008		0.091	0.25		2.73	0.09			
JAV1-B3D	10/22/2008		0.01	0.01		3.11	0.00			
JAV1-B3D	11/19/2008		0.017	0		3.42	0.00	6.31	7.9	0.33
JAV1-B3D	12/17/2008		0	0		2	0.00			
JAV1-B3D	1/23/2009		0.03	0		3.98	0.00			
JAV1B3D	2/17/2009		0.007	0		3.3	0.00			0.17
JAV1B3D	3/24/2009			0.1		2.99	0.03	6.47	6.9	
JAV1B3D	4/21/2009			0		2.51	0.00	6.57	8.3	0.36
JAV1B3D	5/28/2009			0.09		2.32	0.04	6.7	4.6	
JAV1B3D	6/29/2009		0.04	0.03		3.1	0.01	6.5	5.4	1.84
JAV1B3D	7/21/2009			0.12		2.69	0.04	7.5	8.4	
JAV1B3D	8/18/2009			0.01		2.85	0.00	6.9	0.62	1.7
JAV1B3D	9/15/2009			0.11		2.91	0.04	6.54	1.8	
JAV1B3D	10/20/2009		0.02	0.06		3.41	0.02	6.8	0.7	0.91
JAV1B3D	11/17/2009			0.02		3.57	0.01	6.6	7.9	

JAV1B3D	12/15/2009		0.01	3.36	0.00	6.65	0.58	6.27
JAV1B3D	1/19/2010		0	3.09	0.00	6.35	6.9	
JAV1B3D	2/18/2010	0.03	0.05	2.93	0.02	6.22	6.5	7.81
JAV1B3D	3/16/2010		0.01	2.84	0.00	6	1.95	
JAV1B3D	4/22/2010		0.01	3.22	0.00	6.38	1.34	
JAV1B3D	5/18/2010		0.03	3.04	0.01	6.95	0.35	

Block 1, Transect C, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-c1s	1/12/2005	0.17	0.05	1.70	0.35	1.5						
Jav1-c1s	1/26/2005	0.02	0.05	9.40	0.08	0.29						
Jav1-c1s	2/9/2005	0.02	0.05	11.60	0.34	0.98						
Jav1-c1s	2/23/2005	0.03	0.11	10.50	1.2	2.5						
Jav1-c1s	3/10/2005	0.005	0.05	11.20	0.005	0.45						
Jav1-c1s	3/23/2005	0.02	0.05	10.40	0.04	0.25						
Jav1-c1s	4/6/2005	0.05	0.05	0.05	0.06	0.47	2	2	0.03			
Jav1-c1s	4/20/2005	0.005	0.05	7.30	0.12	0.52	1.7	3.9	1.87			
Jav1-c1s	5/5/2005	0.005	0.05	7.40	0.06	0.39	1.6	1.9	3.89			
Jav1-c1s	5/18/2005	0.005	1.1	8.00	0.39	1.8	1.7	5.1	1.57			
Jav1-c1s	6/2/2005	0.005	0.05	8.40	0.68	1.7	2.3	6	1.40			
Jav1-c1s	6/29/2005	0.05	0.66	1.90	1.4	3.4	2.5	3.5	0.54			
Jav1-c1s	12/1/2005	0.005	0.05	25.30			2.5	52.5	0.48			
Jav1-c1s	1/12/2006	0.005	0.05	30.70			4.6	36.8	0.83			
Jav1-c1s	2/9/2006	0.005	0.05	23.30			5.7	27.5	0.85			
Jav1-c1s	3/9/2006	0.005	0.05	20.70			4	25.3	0.82			
JAV1-C1S	10/18/2006	0.07	0.05	8.20			4.7	3	2.73			
JAV1-C1S	11/21/2006	0.03	0.05	28.40			3.6	12.8	2.22			
JAV1-C1S	12/20/2006	0.12	0.05	28.10			5.5	10.4	2.70			
JAV1-C1S	1/24/2007	0.01	0.05	16.40			2.7	8	2.05			
JAV1-C1S	2/21/2007	0.06	0.05	13.50			5.4	5.8	2.33			
JAV1-C1S	3/21/2007	0.02	0.05	10.90			4.6	4.6	2.37			
JAV1-C1S	4/1/07	0.06	0.05	11.20			3.9	5.5	2.04			
JAV1-C1S	4/22/2008	0.07	0.01	4.25			5.33	48.32	0.09			
JAV1-C1S	5/13/2008	0.07	0.06	12.60			5.28	4.58	2.75			
JAV1-C1S	7/8/2008		0.014	5.98				1.41	4.24			
JAV1-C1S	12/17/2008		0	9.52				4.25	2.24			
JAV1-C1S	1/23/2009		0.02	8.18				6.13	1.33			
JAV1C1S	3/24/2009			12.46				3.15	3.96	2.6	14.1	
JAV1C1S	4/21/2009			13.12				2.49	5.27	2.92	13.4	1.8
JAV1C1S	11/17/2009			8.55				3.87	2.21	1.9	9.1	
JAV1C1S	12/15/2009			4.71				3.53	1.33	1.66	1.96	7.01
JAV1C1S	1/19/2010			11.72				5.83	2.01	3.58	12.2	
JAV1C1S	2/18/2010		0.02	4.53				2.72	1.67	1.37	6.8	3.57
JAV1C1S	3/16/2010			4.79				2.63	1.82	1.3	2.23	
JAV1C1S	4/22/2010			7.81				3.63	2.15	1.62	2.95	

Block 1, Transect C, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-c1d	1/12/2005	0.1	0.05	6.4	0.37	0.34						
Jav1-c1d	1/26/2005	0.09	0.05	6.5	0.18	0.48						
Jav1-c1d	2/9/2005	0.12	0.05	7.1	0.34	0.44						
Jav1-c1d	2/23/2005	0.09	0.05	7.6	0.24	0.53						
Jav1-c1d	3/10/2005	0.05	0.05	7.6	0.12	0.55						
Jav1-c1d	3/23/2005	0.02	0.05	0.62	0.2	0.38						
Jav1-c1d	4/20/2005	0.005	0.05	7.7	0.13	0.53	1.1	9.3	0.83			
Jav1-c1d	5/5/2005	0.01	0.05	7.7	0.18	0.58	0.5	2.5	3.08			
Jav1-c1d	4/6/2005	0.005	0.05	7.5	0.26	0.79	0.5	15.4	0.49			
Jav1-c1d	5/18/2005	0.005	0.05	8.1	0.19	0.53	0.5	9.5	0.85			
Jav1-c1d	6/2/2005	0.01	0.05	8	0.31	0.73	1.6	11.5	0.70			
Jav1-c1d	6/15/2005	0.01	0.05	8.6	0.34	0.93	0.5	7.9	1.09			
Jav1-c1d	6/29/2005	0.005	0.05	10	0.19	0.72	0.5	8.2	1.22			
Jav1-c1d	7/13/2005	0.02	0.05	10.9	0.16	0.24	0.5	8.5	1.28			
Jav1-c1d	7/27/2005	0.01	0.05	11.8			2.7	12.1	0.98			
Jav1-c1d	8/10/2005	0.005	0.05	11.3			1.2	10.5	1.08			
Jav1-c1d	8/23/2005	0.01	0.05	11.8			0.5	10.3	1.15			
Jav1-c1d	9/29/2005	0.03	0.05	11.9			0.5	10.1	1.18			
Jav1-c1d	10/27/2005	0.03	0.05	11.4			0.5	9.7	1.18			
Jav1-c1d	12/1/2005	0.005	0.05	16.7			1.5	27.6	0.61			
Jav1-c1d	1/12/2006	0.005	0.05	23.1			1.9	35	0.66			
Jav1-c1d	2/9/2006	0.005	0.05	20.9			2.8	30.6	0.68			
Jav1-c1d	3/9/2006	0.01	0.05	19.2			3.4	28.7	0.67			
Jav1-c1d	4/13/2006	0.01	0.05	16.6			1.7	23.9	0.69			
Jav1-c1d	5/12/2006	0.02	0.05	16.2			1.3	21	0.77			
Jav1-c1d	6/8/2006	0.005	0.05	4.9			1.5	9.9	0.49			
Jav1-c1d	8/10/2006	0.05	0.19	12.3			2.2	15	0.82			
JAV1-C1D	9/20/2006	0.06	0.05	12.1			2.2	8.1	1.49			
JAV1-C1D	10/18/2006	0.06	0.05	12.1			2.2	7.1	1.70			
JAV1-C1D	11/21/2006	0.03	0.05	14.5			1.6	7.5	1.93			
JAV1-C1D	12/20/2006	0.07	0.05	16.7			1.5	9.5	1.76			
JAV1-C1D	1/24/2007	0.04	0.05	15.4			1.4	11.1	1.39			
JAV1-C1D	2/21/2007	0.05	<0.1	14.6			1.7	8.4	1.74			
JAV1-C1D	3/21/2007	0.04	<0.1	14			2	9.1	1.54			
JAV1-C1D	4/1/2007	0.05	<0.1	13.8			1.4	9.1	1.52			
JAV1-C1D	5/1/2007	0.07	<0.1	11.3			1.5	6	1.88			
JAV1-C1D	6/1/2007	0.13	<0.1	11.3			1.6	5.5	2.05			
JAV1-C1D	7/1/2007	0.19	0.1	11.2			2.4	7.1	1.58			
JAV1-C1D	8/20/2007	0.23	<0.1	11.1			1.9	6.5	1.71			
JAV1-C1D	9/17/2007	0.51	0.1	11			2.2	7.4	1.49			
JAV1-C1D	11/24/2007	0.09	<0.1	21			2.4	8.4	2.50			

JAV1-C1D	4/22/2008	0.22	0.01	17.47		4.98	460	0.04				
JAV1-C1D	5/13/2008	0.23	0.07	23.13		4.58	10.66	2.17				
JAV1-C1D	6/10/2008	0.2	0.01	14.04		5.24	11.65	1.21				
JAV1-C1D	7/8/2008		0.073	13.24			8.81	1.50				
JAV1C1D	8/6/2008		0.04	12.19			9.69	1.26				16.3
JAV1-C1D	10/22/2008		0.04	12.37			7.88	1.57				
JAV1-C1D	11/19/2008		0.013	13.21			7.92	1.67				1.98
JAV1-C1D	12/17/2008		0	13.91			7.21	1.93				
JAV1-C1D	1/23/2009		0.03	13.49			10.42	1.29				
JAV1C1D	2/17/2009		0.019	12.71			6.93	1.83				1.45
JAV1C1D	3/24/2009			10.99			6.79	1.62	4.83	14.9		
JAV1C1D	4/21/2009			10.67			5.91	1.81	4.9	14.1	1.13	
JAV1C1D	5/28/2009			13.47			5.84	2.31	5.2	10.9		
JAV1C1D	6/29/2009		0.04	14.4			6.46	2.23	5.3	12.1	2.74	
JAV1C1D	7/21/2009			14.79			5.94	2.49	6.3	17.2		
JAV1C1D	8/18/2009			13.9			5.3	2.62	5.4	1.33	2.63	
JAV1C1D	9/15/2009			12.43			5.01	2.48	4.88	2.9		
JAV1C1D	11/17/2009			13.58			6.22	2.18	5.2	13.8		
JAV1C1D	12/15/2009			12.42			6.4	1.94	4.43	4.9	6.79	
JAV1C1D	1/19/2010			5.52			3.11	1.77	1.16	8.1		
JAV1C1D	2/18/2010		0.03	10.3			5.42	1.90	3.64	11.9	2.38	
JAV1C1D	3/16/2010			10.03			5.45	1.84	3.3	2.21		
JAV1C1D	4/22/2010			9.58			5.61	1.71	4.19	2.8		
JAV1C1D	5/18/2010			10.03			6.4	1.57	4.18	0.18		

Block 1, Transect C, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-c2s	1/12/2005	0.06	0.05	9.2	0.23	0.48						
Jav1-c2s	1/26/2005	0.08	0.05	8.7	0.8	1.8						
Jav1-c2s	2/9/2005	0.04	0.05	9.3	0.31	1.2						
Jav1-c2s	2/23/2005	0.06	0.05	8.3	0.37	1.1						
Jav1-c2s	3/10/2005	0.05	0.05	10.3	0.3	1.2						
Jav1-c2s	3/23/2005	0.01	0.05	0.05	0.32	0.94						
Jav1-c2s	4/6/2005	0.005	0.05	7.3	0.22	1.1	1.9	7.9	0.92			
Jav1-c2s	4/20/2005	0.005	0.05	9.6	0.19	0.9	1	18.6	0.52			
Jav1-c2s	5/18/2005	0.005	0.05	9.5	0.22	1.3	1.1	10.2	0.93			
Jav1-c2s	6/2/2005	0.02	0.05	9.3	0.34	2.3	2.3	11.5	0.81			
Jav1-c2s	6/15/2005	0.01	0.05	9.5	0.24	1.2	0.5	8.5	1.12			
Jav1-c2s	6/29/2005	0.01	0.05	9.3	0.28	1.2	0.5	8.3	1.12			
Jav1-c2s	7/13/2005	0.005	0.05	9.6	0.26	0.74	0.5	8.7	1.10			
Jav1-c2s	7/27/2005	0.03	0.05	10.2			1.4	12.1	0.84			
Jav1-c2s	8/10/2005	0.01	0.05	8.8			1.5	10.6	0.83			

Jav1-c2s	8/23/2005	0.02	0.05	9.4	0.5	11	0.85		
Jav1-c2s	9/29/2005	0.04	0.05	9.7	0.5	10.7	0.91		
Jav1-c2s	10/27/2005	0.04	0.05	9.9	1.1	11	0.90		
Jav1-c2s	12/1/2005	0.02	0.05	9.4	1.1	8.5	1.11		
Jav1-c2s	1/12/2006	0.005	0.05	1.7	2.4	6.7	0.25		
Jav1-c2s	2/9/2006	0.005	0.05	0.42	3.7	6.5	0.06		
Jav1-c2s	3/9/2006	0.13	0.17	0.37	3.4	14.3	0.03		
Jav1-c2s	4/13/2006	0.02	0.05	2.2	1.3	8.5	0.26		
Jav1-c2s	5/12/2006	0.03	0.05	0.78	1.7	5.2	0.15		
Jav1-c2s	6/8/2006	0.01	0.05	7.4	0.5	11.6	0.64		
Jav1-c2s	8/10/2006	0.02	0.05	8.8	1.7	9.4	0.94		
JAV1-C2S	9/20/2006	0.04	0.05	8.8	1.6	6.7	1.31		
JAV1-C2S	10/18/2006	0.03	0.05	9.6	1.3	6.3	1.52		
JAV1-C2S	11/21/2006	0.03	0.05	9.5	1.2	5.9	1.61		
JAV1-C2S	12/20/2006	0.03	0.05	10	1.2	6.1	1.64		
JAV1-C2S	1/24/2007	0.03	0.05	10.2	1	7.4	1.38		
JAV1-C2S	2/21/2007	0.02	0.05	9	1.2	5.5	1.64		
JAV1-C2S	3/21/2007	0.02	0.05	8.5	0.5	5.9	1.44		
JAV1-C2S	4/1/2007	0.03	0.05	8.5	1	6.1	1.39		
JAV1-C2S	5/1/2007	0.04	0.05	8.9	1.5	5.6	1.59		
JAV1-C2S	6/1/2007	0.03	0.05	8.3	0.5	5	1.66		
JAV1-C2S	7/1/2007	0.04	0.05	8.7	1	6.2	1.40		
JAV1-C2S	8/20/2007	0.05	0.05	6.7	0.5	7.7	0.87		
JAV1-C2S	9/17/2007	0.06	0.05	8.8	1.1	7.3	1.21		
JAV1-C2S	10/24/2007	0.13	0.23	8.7	3.5	6.7			
JAV1-C2S	11/24/2007	0.03	< 0.1	2.6	4.1	6.2			
JAV1-C2S	4/22/2008	0.09	0.01	0.08	5.45	44.61	0.00		
JAV1-C2S	5/13/2008	0.09	0.02	0.11	5.32	3.14	0.04		
JAV1-C2S	6/10/2008	0.12	0.01	4.56	6.22	7.95	0.57		
JAV1-C2S	7/8/2008		0.024	8.49		7.38	1.15		
JAV1C2S	8/6/2008		0.01	9.77		9.99	0.98		16.13
JAV1-C2S	9/24/2008		0.018	9.9		10.26	0.96		
JAV1-C2S	11/19/2008		0.014	10.34		10.33	1.00		3.62
JAV1-C2S	12/17/2008		0	10.25		10.19	1.01		
JAV1-C2S	1/23/2009		0.04	0		8.07	0.00		
JAV1C2S	2/17/2009		0	0		4.28	0.00		0.99
JAV1C2S	3/24/2009			4.12		6.62	0.62		
JAV1C2S	4/21/2009			2.7		5.11	0.53		1.49
JAV1C2S	5/28/2009			5.25		6.05	0.87		
JAV1C2S	6/29/2009		0.03	10.34		9.63	1.07	6	14.7
JAV1C2S	7/21/2009			10.13		9.77	1.04		2.54
JAV1C2S	8/18/2009			11.17		9.23	1.21		
JAV1C2S	10/20/2009		0.02	10.8		10.6	1.02		
JAV1C2S	11/17/2009			11.22		9.59	1.17		
JAV1C2S	12/15/2009			6.82		8.28	0.82		7.53

JAV1C2S	1/19/2010			3.53						4.79	0.74	
JAV1C2S	2/18/2010		0.02	10.85						9.77	1.11	2.51
JAV1C2S	3/16/2010			10.72						9.73	1.10	
JAV1C2S	4/22/2010			10.58						9.98	1.06	
JAV1C2S	5/18/2010			0.31						3.28	0.09	

Block 1, Transect C, Well Position 2(Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-c2d	1/12/2005	0.07	0.33	5.6	0.18	0.44						
Jav1-c2d	1/26/2005	0.04	0.05	5.8	0.12	0.33						
Jav1-c2d	2/9/2005	0.02	0.05	6.3	0.03	0.42						
Jav1-c2d	2/23/2005	0.02	0.05	6.4	0.02	0.27						
Jav1-c2d	3/10/2005	0.02	0.05	6.9	0.005	0.28						
Jav1-c2d	3/23/2005	0.02	0.05	0.13	0.05	0.24						
Jav1-c2d	4/20/2005	0.005	0.05	6.3	0.06	0.57	0.5	9.7	0.65			
Jav1-c2d	5/5/2005	0.02	0.05	9.7	0.08	0.61	0.5	2.5	3.88			
Jav1-c2d	5/5/2005	0.01	0.05	6.2	0.06	0.78	0.5	3.2	1.94			
Jav1-c2d	4/6/2005	0.005	0.05	6.2	0.08	0.8	1.1	10.2	0.61			
Jav1-c2d	5/18/2005	0.005	0.05	6.3	0.08	0.62	1.2	10.9	0.58			
Jav1-c2d	6/2/2005	0.05	0.05	6.4	0.05	0.45	2.4	11.6	0.55			
Jav1-c2d	6/15/2005	0.01	0.05	6.2	0.02	0.3	0.5	8.8	0.70			
Jav1-c2d	6/29/2005	0.01	0.05	6.2	0.005	0.37	0.5	8.7	0.71			
Jav1-c2d	7/13/2005	0.01	0.05	6.6	0.06	0.12	0.5	9.3	0.71			
Jav1-c2d	7/27/2005	0.005	0.05	6.8			1.8	12.9	0.53			
Jav1-c2d	8/10/2005	0.005	0.05	6.3			0.5	11.2	0.56			
Jav1-c2d	8/23/2005	0.01	0.05	6.8			0.5	11.8	0.58			
Jav1-c2d	9/29/2005	0.04	0.05	6.5			0.5	11.6	0.56			
Jav1-c2d	10/27/2005	0.02	0.05	6.4			1.3	11.5	0.56			
Jav1-c2d	12/1/2005	0.01	0.05	6.3			1.4	9.2	0.68			
Jav1-c2d	1/12/2006	0.02	0.05	6.6			1.3	9.5	0.69			
Jav1-c2d	2/9/2006	0.02	0.05	6.6			1.7	9.3	0.71			
Jav1-c2d	3/9/2006	0.02	0.05	6.4			8	8.9	0.72			
Jav1-c2d	4/13/2006	0.04	0.05	6			0.5	9.9	0.61			
Jav1-c2d	5/12/2006	0.03	0.05	6.4			0.5	8.4	0.76			
Jav1-c2d	6/8/2006	0.02	0.05	6.3			0.5	11.5	0.55			
Jav1-c2d	8/10/2006	0.07	0.05	7.3			1.3	9.3	0.78			
JAV1-C2D	9/20/2006	0.08	0.13	5.9			1.6	8.8	0.67			
JAV1-C2D	10/18/2006	0.05	0.05	6.6			1.9	7.4	0.89			
JAV1-C2D	11/21/2006	0.02	0.05	6.7			0.5	7.2	0.93			
JAV1-C2D	12/20/2006	0.03	0.05	6.9			0.5	6.4	1.08			
JAV1-C2D	1/24/2007	0.03	0.05	6.8			0.5	8.8	0.77			
JAV1-C2D	2/21/2007	0.05	< 0.1	6			1.2	6.5	0.92			

JAV1-C2D	3/21/2007	0.02	< 0.1	6.4		< 1	7.2	0.89				
JAV1-C2D	5/1/2007	0.05	< 0.1	5.5		1.3	6.1	0.90				
JAV1-C2D	6/1/2007	0.03	< 0.1	6.4		< 1	6.8	0.94				
JAV1-C2D	7/1/2007	0.03	< 0.1	6.5		< 1	7.5	0.87				
JAV1-C2D	8/20/2007	0.04	< 0.1	9		< 1	7.2	1.25				
JAV1-C2D	9/17/2007	0.04	< 0.1	6.6		1.3	6.9	0.96				
JAV1-C2D	10/24/2007	0.06	< 0.1	6.7		2.3	7.2	0.93				
JAV1-C2D	11/24/2007	0.02	< 0.1	7		1.2	7.4	0.95				
JAV1-C2D	4/22/2008	0.23	0.02	6.81		3.82	73.56	0.09				
JAV1-C2D	5/13/2008	0.24	0.05	19.83		4.52	9.75	2.03				
JAV1-C2D	6/10/2008	0.21	0.00	7.04		4.14	11.26	0.63				
JAV1-C2D	7/8/2008		0.171	7.02			10.75	0.65				
JAV1C2D	8/6/2008		0.02	7.27			11.26	0.65				16.4
JAV1-C2D	9/24/2008		0.067	6.98			11.39	0.61				
JAV1-C2D	10/22/2008		0.05	7.32			11.77	0.62				
JAV1-C2D	11/19/2008		0.008	7.18			11.31	0.63				2.1
JAV1-C2D	12/17/2008		0	7.06			11.06	0.64				
JAV1-C2D	1/23/2009		0.03	7.1			16.13	0.44				
JAV1C2D	2/17/2009		0	6.96			10.17	0.68				0.91
JAV1C2D	3/24/2009			7.17			10.2	0.70				
JAV1C2D	4/21/2009			6.96			9.85	0.71				0.92
JAV1C2D	5/28/2009			7.4			10.25	0.72				
JAV1C2D	6/29/2009		0.09	7.65			10.47	0.73	7	12.2		1.9
JAV1C2D	7/21/2009			7			10.55	0.66				
JAV1C2D	8/18/2009			7.65			10.03	0.76	7.3	1.11		1.74
JAV1C2D	9/15/2009			7.95			10.57	0.75				
JAV1C2D	10/20/2009		0.05	7.77			11.81	0.66				3.9
JAV1C2D	11/17/2009			7.93			10.82	0.73				
JAV1C2D	12/15/2009			7.87			11.37	0.69				4.72
JAV1C2D	1/19/2010			7.64			10.38	0.74				
JAV1C2D	2/18/2010		0.03	7.71			11.39	0.68				
JAV1C2D	3/16/2010			7.75			10.54	0.74				
JAV1C2D	4/22/2010			7.88			10.8	0.73				

Block 2, Transect C, Well Position 3(Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-c3s	1/12/2005	0.04	0.05	2	0.69	2.1						
Jav1-c3s	1/26/2005	0.08	0.05	3	0.73	1.9						
Jav1-c3s	2/9/2005	0.03	0.05	2.3	0.54	1						
Jav1-c3s	2/23/2005	0.03	0.05	2	0.35	0.73						
Jav1-c3s	3/10/2005	0.04	0.05	1.8	0.74	1.4						
Jav1-c3s	3/23/2005	0.02	0.05	0.57	0.22	0.3						

Jav1-c3s	4/6/2005	0.01	0.05	0.13	0.2	0.98	2.7	4.8	0.03										
Jav1-c3s	4/20/2005	0.005	0.05	1.1	0.24	0.85	3.3	5.1	0.22										
Jav1-c3s	5/5/2005	0.01	0.05	1.4	0.3	1.2	2.9	3.2	0.44										
Jav1-c3s	5/18/2005	0.005	0.05	2.3	0.31	0.82	2.5	6.4	0.36										
Jav1-c3s	6/2/2005	0.02	0.05	2.7	0.21	0.91	3.5	6.4	0.42										
Jav1-c3s	6/15/2005	0.005	0.05	2.5	0.12	0.86	1.5	4.6	0.54										
Jav1-c3s	6/29/2005	0.01	0.05	2	0.08	0.56	0.5	4.6	0.43										
Jav1-c3s	7/13/2005	0.02	0.05	2.4	0.12	0.22	0.5	4.6	0.52										
Jav1-c3s	7/27/2005	0.005	0.05	2.4			1.3	7.8	0.31										
Jav1-c3s	8/10/2005	0.01	0.05	2.2			1.5	6.6	0.33										
Jav1-c3s	8/23/2005	0.01	0.05	2.2			1.6	6.7	0.33										
Jav1-c3s	9/29/2005	0.02	0.05	2.7			1.7	7	0.39										
Jav1-c3s	10/27/2005	0.02	0.05	2.1			1.8	6.8	0.31										
Jav1-c3s	12/1/2005	0.03	0.05	2.7			0.5	4.8	0.56										
Jav1-c3s	1/12/2006	0.005	0.05	3.2			3.6	5.5	0.58										
Jav1-c3s	2/9/2006	0.01	0.05	2.3			3.2	5.7	0.40										
Jav1-c3s	3/9/2006	0.01	0.05	2.8			3.6	5.6	0.50										
Jav1-c3s	4/13/2006	0.03	0.05	2.4			1.1	6.1	0.39										
Jav1-c3s	5/12/2006	0.03	0.05	2.4			0.5	4.3	0.56										
Jav1-c3s	6/8/2006	0.02	0.05	0.35			0.5	3.4	0.10										
Jav1-c3s	8/10/2006	0.03	0.3	2.5			3.2	10.9	0.23										
JAV1-C3S	9/20/2006	0.03	0.05	2.1			1.6	3.1	0.68										
JAV1-C3S	10/18/2006	0.03	0.05	2.1			2.2	3.1	0.68										
JAV1-C3S	11/21/2006	0.02	0.05	0.95			8.8	1.5	0.63										
JAV1-C3S	12/20/2006	0.03	0.05	1.2			3.9	2.5	0.48										
JAV1-C3S	1/24/2007	0.01	0.05	0.95			3.6	3.1	0.31										
JAV1-C3S	2/21/2007	0.03	0.05	1.7			3.8	2.1	0.81										
JAV1-C3S	3/21/2007	0.03	0.05	1.3			3.7	2.5	0.52										
JAV1-C3S	4/1/2007	0.02	0.05	1.8			2	3.6	0.50										
JAV1-C3S	5/1/2007	0.15	0.21	2.1			3.4	3.2	0.66										
JAV1-C3S	6/1/2007	0.03	0.05	2.5			1.1	2.7	0.93										
JAV1-C3S	7/1/2007	0.05	0.05	2.5			1.2	3.5	0.71										
JAV1-C3S	8/20/2007	0.04	0.05	2.5			0.5	3.2	0.78										
JAV1-C3S	9/17/2007	0.03	0.05	3.7			0.5	5.1	0.73										
JAV1-C3S	10/24/2007	0.05	0.11	3.9			2.6	4.6	0.85										
JAV1-C3S	11/24/2007	0.02	0.05	2.8			1.4	2.7	1.04										
JAV1-C3S	4/22/2008	0.11	0.02	0.42			7.8	97.99	0.00										
JAV1-C3S	5/13/2008	0.11	0.02	2.48			9.95	3.55	0.70										
JAV1-C3S	6/10/2008	0.2	0.03	1.85			5.53	6.02	0.31										
JAV1-C3S	7/8/2008		0.016	2.12				3.39	0.63	3.04	6.8								
JAV1C3S	8/6/2008		0.03	2.58				5.84	0.44			16.52							
JAV1-C3S	9/24/2008		0.002	2.53				5.66	0.45										
JAV1-C3S	10/22/2008		0.00	2.58				5.88	0.44										
JAV1-C3S	11/19/2008		0.013	2.04				6.15	0.33	4.16	5.9	5.13							
JAV1-C3S	12/17/2008		0	2.18				4.97	0.44										

JAV1-C3S	1/23/2009	0.02	3.2				13.36	0.24				
JAV1C3S	2/17/2009	0	1.77				10.42	0.17	5.6	13.3	1.82	
JAV1C3S	3/24/2009		1.45				5.25	0.28	3.73	10.7		
JAV1C3S	4/21/2009		0.83				4.43	0.19	4.84	12.3	3.21	
JAV1C3S	5/28/2009		2.24				5.13	0.44	6.4	9.7		
JAV1C3S	6/29/2009	0.05	2.55				4.89	0.52	6.9	12.1		
JAV1C3S	7/21/2009		2.31				5.69	0.41	7.5	15.9		
JAV1C3S	8/18/2009		2.69				5.5	0.49	6.9	1.15	1.47	
JAV1C3S	9/15/2009		3				6.23	0.48	6.66	3.1		
JAV1C3S	10/20/2009	0.02	3.15				7.05	0.45	6.9	1.93	3.24	
JAV1C3S	11/17/2009		2.13				5.72	0.37	6.1	11		
JAV1C3S	12/15/2009		1.46				7.78	0.19	4.64	4.1	11.69	
JAV1C3S	1/19/2010		0.81				6.62	0.12	3.94	11.3		
JAV1C3S	2/18/2010	0.02	0.56				3.97	0.14	3.43	9.1	9.03	
JAV1C3S	3/16/2010		0.63				4.83	0.13	3.5	2.35		
JAV1C3S	4/22/2010		0.87				4.94	0.18	4.36	2.22		
JAV1C3S	5/18/2010		0.64				4.06	0.16	4.38	0.16		

Block 1, Transect C, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav1-c3d	1/12/2005	0.05	0.05	2.2	0.64	1.6						
Jav1-c3d	1/26/2005	0.05	0.05	2.4	0.54	1.3						
Jav1-c3d	2/9/2005	0.04	0.05	2.3	0.47	0.81						
Jav1-c3d	2/23/2005	0.06	0.05	2.2	0.52	0.77						
Jav1-c3d	3/10/2005	0.06	0.05	2	0.68	1						
Jav1-c3d	3/23/2005	0.005	0.05	5.7	0.44	0.2						
Jav1-c3d	4/20/2005	0.005	0.05	2	0.3	0.82	1.4	5.7	0.35			
Jav1-c3d	5/5/2005	0.02	0.05	1.9	0.3	1.2	1.7	3.8	0.50			
Jav1-c3d	4/6/2005	0.01	0.05	0.05	0.26	0.43	2	3.1	0.02			
Jav1-c3d	5/18/2005	0.005	0.05	2.2	0.22	0.91	1.4	6.1	0.36			
Jav1-c3d	6/2/2005	0.03	0.05	2.5	0.3	0.69	2.5	6.3	0.40			
Jav1-c3d	6/15/2005	0.01	0.05	2.2	0.16	0.65	0.5	4.6	0.48			
Jav1-c3d	6/29/2005	0.02	0.05	2.3	0.19	0.61	0.5	4.7	0.49			
Jav1-c3d	7/13/2005	0.005	0.05	2.6	0.09	0.4	0.5	4.9	0.53			
Jav1-c3d	7/27/2005	0.1	0.05	2.9			1.3	8.3	0.35			
Jav1-c3d	8/10/2005	0.01	0.05	2.4			1.1	6.8	0.35			
Jav1-c3d	8/23/2005	0.02	0.05	2.5			0.5	6.9	0.36			
Jav1-c3d	9/29/2005	0.04	0.05	2.6			0.5	7	0.37			
Jav1-c3d	10/27/2005	0.03	0.05	2.6			0.5	7	0.37			
Jav1-c3d	12/1/2005	0.02	0.05	2.4			0.5	4.5	0.53			
Jav1-c3d	1/12/2006	0.02	0.05	2.6			1.6	5.4	0.48			
Jav1-c3d	2/9/2006	0.02	0.05	2.4			1.3	5.3	0.45			

Jav1-c3d	3/9/2006	0.06	0.05	2.7	10.7	6.7	0.40			
Jav1-c3d	4/13/2006	0.03	0.05	2.5	0.5	4.8	0.52			
Jav1-c3d	5/12/2006	0.02	0.05	2.5	0.5	4.5	0.56			
Jav1-c3d	6/8/2006	0.01	0.15	2.5	0.5	10.4	0.24			
Jav1-c3d	8/10/2006	0.03	0.05	2.4	1.5	4.8	0.50			
JAV1-C3D	9/20/2006	0.03	0.05	2	1.2	3.2	0.63			
JAV1-C3D	10/18/2006	0.03	0.05	2.3	0.5	3	0.77			
JAV1-C3D	11/21/2006	0.03	0.05	1.3	3.8	2.3	0.57			
JAV1-C3D	12/20/2006	0.03	0.05	2	1.9	2.5	0.80			
JAV1-C3D	1/24/2007	0.02	0.05	1.6	2	3.6	0.44			
JAV1-C3D	2/21/2007	0.02	0.05	2	1.9	3	0.67			
JAV1-C3D	3/21/2007	0.02	0.05	2	2.4	3	0.67			
JAV1-C3D	Apr-07	0.03	0.05	2.1	1.1	3.5	0.60			
JAV1-C3D	May-07	0.03	0.05	2.3	1.2	2.9	0.79			
JAV1-C3D	Jun-07	0.03	0.05	1.8	0.5	2.1	0.86			
JAV1-C3D	Jul-07	0.03	0.05	2.3	0.5	3	0.77			
JAV1-C3D	Aug-07	0.03	0.05	3.5	1.1	4.9	0.71			
JAV1-C3D	Sep-07	0.05	0.05	2.5	0.5	3.9	0.64			
JAV1-C3D	Oct-07	0.06	0.05	2.7	1.5	3.3	0.82			
JAV1-C3D	Nov-07	0.03	0.05	2.6	1.3	2.7	0.96			
JAV1-C3D	4/22/2008	0.16	0.01	0.78	6.11	61.55	0.01			
JAV1-C3D	5/13/2008	0.19	0.02	4.4	8.63	4.8	0.92			
JAV1-C3D	6/10/2008	0.19	0.00	1.98	5.18	5.97	0.33			
JAV1-C3D	7/8/2008		0.014	2.14		3.4	0.63	6.21	12	
JAV1C3D	8/6/2008		0.03	2.27		5.47	0.41			16.34
JAV1-C3D	9/24/2008		0.011	2.41		5.41	0.45			
JAV1-C3D	10/22/2008		0.00	2.57		5.35	0.48			
JAV1-C3D	11/19/2008		0.01	2.4		6.08	0.39	6.4	13.2	1.69
JAV1-C3D	12/17/2008		0	2.44		4.88	0.50			
JAV1-C3D	1/23/2009		0.02	2.41		11.41	0.21			
JAV1C3D	2/17/2009		0.004	2.1		7.58	0.28	6.6	12.8	0.87
JAV1C3D	3/24/2009			1.39		6.48	0.21	5.52	11.8	
JAV1C3D	4/21/2009			1.47		4.75	0.31	5.76	12.2	1.97
JAV1C3D	5/28/2009			2.18		5.19	0.42	6.5	10.3	
JAV1C3D	6/29/2009		0.03	2.28		5.83	0.39	6.4	11.5	1.52
JAV1C3D	7/21/2009			2.18		5.44	0.40	7.2	14.5	
JAV1C3D	8/18/2009			2.5		5.5	0.45	6.7	1.08	1.53
JAV1C3D	9/15/2009			2.42		5.78	0.42	6.49	3.3	
JAV1C3D	10/20/2009		0.01	2.52		6	0.42	6.8	1.85	3.03
JAV1C3D	11/17/2009			2.65		5.88	0.45	6.3	13.2	
JAV1C3D	12/15/2009			1.92		8.03	0.24	5.32	4.5	6.25
JVA1C3D	1/19/2010			1		6.64	0.15	4.71	11.9	
JAV1C3D	2/18/2010		0.02	0.8		4.19	0.19	3.89	10	7.55
JAV1C3D	3/16/2010			1.04		5.19	0.20	4.5	2.8	
JAV1C3D	4/22/2010			1.31		5.06	0.26	4.97	2.6	

JAV1C3D 5/18/2010 1.51 5.59 0.27 6.19 1.33

Block 2, Transect A, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-a1s	1/12/2005	0.17	0.46	0.11	0.49	2.3						
Jav2-a1s	1/26/2005	0.07	0.05	0.60	0.59	2						
Jav2-a1s	2/9/2005	0.01	0.05	0.94	0.41	1.8						
Jav2-a1s	2/23/2005	0.02	0.05	1.00	0.34	1.6						
Jav2-a1s	3/10/2005	0.005	0.05	1.30	0.07	0.6						
Jav2-a1s	3/23/2005	0.05	0.05	2.90	0.38	5.1						
Jav2-a1s	4/20/2005	0.005	0.05	1.40	0.17	1.1	2.3	0.5	2.80			
Jav2-a1s	5/5/2005	0.01	0.05	1.20	0.15	1.3	1	7.2	0.17			
Jav2-a1s	4/6/2005	0.005	0.05	1.50	0.22	0.92	1.4	0.5	3.00			
Jav2-a1s	5/18/2005	0.005	0.05	1.30	0.11	1.1	2.3	14.6	0.09			
Jav2-a1s	6/2/2005	0.005	0.2	1.20	0.27	1.3	2.2	14.5	0.08			
Jav2-a1s	6/29/2005	0.005	0.34	0.51	0.26	1.2	1	11.7	0.04			
Jav2-a1s	1/12/2006	0.02	0.05	1.70			2.6	16.3	0.10			
Jav2-a1s	2/9/2006	0.005	0.05	0.61			2.5	18.6	0.03			
Jav2-a1s	3/9/2006	0.01	0.05	0.34			2.1	17	0.02			
Jav2-a1s	4/13/2006	0.005	0.05	0.35			2.2	12.9	0.03			
Jav2-a1s	6/8/2006	0.005	0.05	0.20			1.4	12	0.02			
Jav2-a1s	8/10/2006	0.17	0.55	1.40			3.9	12.6	0.11			
JAV2-A1S	9/20/2006	0.03	0.12	0.12			1.9	9.3	0.01			
JAV2-A1S	10/18/2006	0.04	0.05	0.14			1.8	8.1	0.02			
JAV2-A1S	11/21/2006	0.19	0.23	0.12			2.5	7.7	0.02			
JAV2-A1S	12/20/2006	0.005	0.05	0.26			1.5	7.4	0.04			
JAV2-A1S	1/24/2007	0.02	0.05	0.05			1.7	9.2	0.01			
JAV2-A1S	2/21/2007	0.02	0.05	0.23			1.9	7.5	0.03			
JAV2-A1S	3/21/2007	0.005	0.05	0.20			1.7	8.5	0.02			
JAV2-A1S	4/1/2007	0.01	0.05	0.18			1.3	9.1	0.02			
JAV2-A1S	5/1/2007	0.1	0.3	0.39			2.1	8.4	0.05			
JAV2-A1S	11/24/2007	0.13	0.05	8.20			2.6	5.9	1.39			
JAV2-A1S	4/22/2008	0.1	0.06	9.72			4.92	400	0.02			
JAV2-A1S	5/13/2008	0.11	0.06	23.13			5.53	7.46	3.10			
JAV2-A1S	6/10/2008	0.09	0.01	8.27			4.9	8.94	0.93			
JAV2-A1S	7/8/2008		0.061	4.60				9.19	0.50			
JAV2A1S	8/6/2008		0.06	6.95				9.3	0.75			19.6
JAV2-A1S	12/17/2008		0	8.63				8.06	1.07			
JAV2-A1S	1/23/2009		0.01	5.69				17.46	0.33			
JAV2A1S	3/24/2009			2.27				6.41	0.35	6.31	3.3	
JAV2A1S	4/21/2009			2.27				6.02	0.38	5.73	4.2	1.44
JAV2A1S	9/15/2009			0.37				11.96	0.03			

JAV2A1S	11/17/2009		4.57		5.17	0.88	6.6	4.8			
JAV2A1S	12/15/2009		1.22		6.73	0.18					
JAV2A1S	1/19/2010		1.06		5.12	0.21	4.67	3.5			
JAV2A1S	2/18/2010	0.02	1.51		5.37	0.28	4.81	3.8	2.48		
JAV2A1S	3/16/2010		1.68		5.67	0.30	4.6	1.14			
JAV2A1S	4/22/2010		1.02		7.39	0.14	4.53	0.64			
JAV2A1S	5/18/2010		0.44		5.03	0.09	4.79	0			

Block 2, Transect A, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-a1d	1/12/2005	0.07	0.05	0.05	0.47	0.38						
Jav2-a1d	1/26/2005	0.04	0.05	0.16	0.32	0.16						
Jav2-a1d	2/9/2005	0.02	0.05	0.26	0.33	0.28						
Jav2-a1d	2/23/2005	0.04	0.05	0.35	0.58	0.51						
Jav2-a1d	3/10/2005	0.01	0.05	0.49	0.1	0.21						
Jav2-a1d	3/23/2005	0.01	0.05	0.45	0.68	0.05						
Jav2-a1d	4/6/2005	0.01	0.05	7.1	0.27	0.73	1.6	9.2	0.77			
Jav2-a1d	4/20/2005	0.005	0.05	0.71	0.12	0.93	1.5	11.1	0.06			
Jav2-a1d	5/5/2005	0.02	0.11	0.64	0.14	0.9	1.1	3.4	0.19			
Jav2-a1d	5/18/2005	0.005	0.05	0.92	0.15	0.82	0.5	11.4	0.08			
Jav2-a1d	6/2/2005	0.01	0.05	0.76	0.17	0.43	2.5	12.3	0.06			
Jav2-a1d	6/15/2005	0.43	8.1	0.23	0.96	9.9	1.3	9.9	0.02			
Jav2-a1d	6/29/2005	0.02	0.05	0.85	0.06	0.53	0.5	9.3	0.09			
Jav2-a1d	7/13/2005	0.005	0.05	0.74	0.005	0.27	0.5	9.9	0.07			
Jav2-a1d	7/27/2005	0.03	0.18	1.4			1.2	13	0.11			
Jav2-a1d	8/10/2005	0.005	0.05	0.78			1.3	11.4	0.07			
Jav2-a1d	8/23/2005	0.01	0.05	0.84			1.3	11.9	0.07			
Jav2-a1d	9/29/2005	0.02	0.05	0.7			1.4	12.2	0.06			
Jav2-a1d	10/27/2005	0.02	0.05	0.97			1	11.4	0.09			
Jav2-a1d	12/1/2005	0.02	0.05	1.1			0.5	9	0.12			
Jav2-a1d	1/12/2006	0.01	0.05	0.93			0.5	11.1	0.08			
Jav2-a1d	2/9/2006	0.005	0.05	1			0.5	11.3	0.09			
Jav2-a1d	3/9/2006	0.01	0.05	0.92			1.6	10.7	0.09			
Jav2-a1d	4/13/2006	0.005	0.05	0.92			0.5	10.1	0.09			
Jav2-a1d	5/12/2006	0.01	0.05	0.87			0.5	10.2	0.09			
Jav2-a1d	6/8/2006	0.005	0.05	0.86			0.5	13.2	0.07			
Jav2-a1d	8/10/2006	0.05	0.13	0.87			1.3	11.1	0.08			
JAV2-A1D	9/20/2006	0.01	0.05	0.65			1.1	9.1	0.07			
JAV2-A1D	10/18/2006	0.02	0.05	0.79			1.3	8.9	0.09			
JAV2-A1D	11/21/2006	0.07	0.11	0.86			1.9	8.9	0.10			
JAV2-A1D	12/20/2006	0.005	0.05	1			1	8	0.13			
JAV2-A1D	1/24/2007	0.005	0.05	1.1			0.5	10.6	0.10			

JAV2-A1D	2/21/2007	0.02	0.05	1.1			1.1	6.9	0.16			
JAV2-A1D	3/21/2007	0.005	0.05	1.1			1.3	8	0.14			
JAV2-A1D	4/1/2007	0.01	0.05	1			0.5	8.6	0.12			
JAV2-A1D	5/1/2007	0.02	0.05	1.1			0.5	7.5	0.15			
JAV2-A1D	6/1/2007	0.05	0.24	0.7			1.2	4.9	0.14			
JAV2-A1D	7/1/2007	0.05	0.12	1			0.5	8.5	0.12			
JAV2-A1D	8/20/2007	0.05	0.05	1			0.5	8.4	0.12			
JAV2-A1D	9/17/2007	0.03	0.05	1.1			0.5	9	0.12			
JAV2-A1D	10/24/2007	0.03	0.05	1.1			2.1	8.3	0.13			
JAV2-A1D	11/24/2007	0.03	0.05	1.3			1.4	7.3	0.18			
JAV2-A1D	4/22/2008	0.47	0.04	1.43			4.54	46.97	0.03			
JAV2-A1D	5/13/2008	0.25	0.07	21.4			5.08	10.6	2.02			
JAV2-A1D	6/10/2008	0.2	0.04	1.45			4.99	12.23	0.12			
JAV2-A1D	7/8/2008		0.042	1.29				9.13	0.14			
JAV2-A1D	7/8/2008		0.187	7.14				6.58	1.09			
JAV2A1D	8/6/2008		0.03	1.4				11.88	0.12			16.16
JAV2-A1D	9/24/2008		0.045	1.7				11.74	0.14			
JAV2-A1D	10/22/2008		0.03	1.5				11.42	0.13			18.1
JAV2-A1D	11/19/2008		0.014	1.39				12.28	0.11			2.18
JAV2-A1D	12/17/2008		0	1.77				10.84	0.16			
JAV2-A1D	1/23/2009		0.02	1.56				21.71	0.07			
JAV2A1D	2/17/2009		0.029	1.46				11	0.13			0.69
JAV2A1D	3/24/2009			1.61				10.79	0.15	5.82	1.7	
JAV2A1D	4/21/2009			1.39				10.03	0.14	5.76	2.1	0.93
JAV2A1D	5/28/2009			1.52				10.89	0.14	7.2	0.2	
JAV2A1D	6/29/2009		0.05	1.51				11.37	0.13	5.5	0.9	1.92
JAV2A1D	7/21/2009			1.81				11.14	0.16	6.2	2.8	
JAV2A1D	8/18/2009			1.51				11.13	0.14	3.1	0.27	
JAV2A1D	9/15/2009			1.49				12.16	0.12	5.93	0.7	
JAV2A1D	10/20/2009		0.04	1.71				12.25	0.14	6	0	3.95
JAV2A1D	12/15/2009			2.12				11.49	0.18			
JAV2A1D	1/19/2010			1.93				10.74	0.18	5.12	1.7	
JAV2A1D	2/18/2010		0.02	1.92				10.89	0.18	5.74	2	2.55
JAV2A1D	3/16/2010			1.83				10.76	0.17	5.4	0.32	
JAV2A1D	4/22/2010			1.82				10.99	0.17	5.38	0	
JAV2A1D	5/18/2010			1.74				11.47	0.15	6.28	0	

Block 2, Transect A, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-a2s	1/12/2005	0.24	0.15	0.11	0.8	0.45						
Jav2-a2s	1/26/2005	0.09	0.05	0.05	0.18	0.62						
Jav2-a2s	2/9/2005	0.1	0.12	0.05	0.44	1.2						

Jav2-a2s	2/23/2005	0.13	0.05	0.05	0.48	1.5			
Jav2-a2s	3/10/2005	0.02	0.05	0.3	0.02	0.33			
Jav2-a2s	3/23/2005	0.005	0.05	2.3	0.06	0.05			
Jav2-a2s	4/6/2005	0.02	0.05	10.2	0.06	0.71	1.4	3.3	3.09
Jav2-a2s	4/20/2005	0.01	0.05	0.05	0.11	0.33	1	7.1	0.01
Jav2-a2s	5/5/2005	0.005	0.05	0.05	0.05	0.63	0.5	2.9	0.02
Jav2-a2s	5/18/2005	0.005	0.05	0.32	0.07	0.4	1.3	2.9	0.11
Jav2-a2s	6/2/2005	0.005	0.05	0.05	0.07	0.41	2.3	3.2	0.02
Jav2-a2s	6/15/2005	0.005	0.05	0.05	0.05	0.54	0.5	2	0.03
Jav2-a2s	6/29/2005	0.01	0.05	0.05	0.12	0.39	0.5	2	0.03
Jav2-a2s	7/13/2005	0.01	0.05	0.05	0.27	0.43	1.1	2.2	0.02
Jav2-a2s	7/27/2005	0.005	0.05	0.37			1.4	5.9	0.06
Jav2-a2s	8/10/2005	0.01	0.05	0.05			1.7	4.4	0.01
Jav2-a2s	8/23/2005	0.02	0.05	0.05			1.4	4.6	0.01
Jav2-a2s	9/29/2005	0.02	0.05	0.84			1.8	5.7	0.15
Jav2-a2s	10/27/2005	0.02	0.05	0.22			1.6	6.1	0.04
Jav2-a2s	12/1/2005	0.005	0.05	0.05			1.2	4.2	0.01
Jav2-a2s	1/12/2006	0.005	0.05	0.14			1.8	11.7	0.01
Jav2-a2s	2/9/2006	0.005	0.05	0.05			3.4	15.4	0.00
Jav2-a2s	3/9/2006	0.005	0.05	0.13			2.8	13.9	0.01
Jav2-a2s	4/13/2006	0.005	0.05	0.18			1.6	12.2	0.01
Jav2-a2s	5/12/2006	0.005	0.05	0.05			1.7	11.1	0.00
Jav2-a2s	6/8/2006	0.005	0.19	0.05			1.7	16.2	0.00
Jav2-a2s	8/10/2006	0.07	0.23	0.05			2.2	8.1	0.01
JAV2-A2S	9/20/2006	0.1	0.2	0.05			2	2.3	0.02
JAV2-A2S	10/18/2006	0.3	0.05	0.05			2.9	1.6	0.03
JAV2-A2S	11/21/2006	0.005	0.05	0.05			2.4	9.8	0.01
JAV2-A2S	12/20/2006	0.01	0.05	0.05			1.6	5.6	0.01
JAV2-A2S	1/24/2007	0.005	0.05	0.05			1.9	6.1	0.01
JAV2-A2S	2/21/2007	0.01	0.05	0.05			2.3	3.6	0.01
JAV2-A2S	3/21/2007	0.005	0.05	9.6			2.6	21.4	0.45
JAV2-A2S	4/1/2007	0.02	0.05	0.05			1.4	4.9	0.45
JAV2-A2S	5/1/2007	0.05	0.05	0.11			1.2	1.6	0.07
JAV2-A2S	6/1/2007	0.08	0.05	0.05			1.2	1.1	0.07
JAV2-A2S	7/1/2007	0.15	0.05	0.05			1.9	2	0.07
JAV2-A2S	11/24/2007	0.08	0.05	0.05			5	12.6	0.00
JAV2-A2S	4/22/2008	0.1	0.01	0			5.99	18.47	0.00
JAV2-A2S	5/13/2008	0.08	0.03	0.01			6.08	8.71	0.00
JAV2-A2S	6/10/2008	0.08	0.02	0			7.08	7.93	0.00
JAV2-A2S	7/8/2008		0.121	0				6.14	0.00
JAV2-A2S	7/8/2008		0.088	0.16				3.8	0.04
JAV2A2S	8/6/2008		0.07	0.03				6.82	0.00
JAV2-A2S	9/24/2008		0.03	0.03				6.7	0.00
JAV2-A2S	12/17/2008		0	0				5.83	0.00

18.4

JAV2-A2S	1/23/2009	0.03	0				18.6	0.00			
JAV2A2S	2/17/2009	0.004	0				12.16	0.00			1.47
JAV2-A2S	1/23/2009	0.03	0				18.6	0.00			
JAV2A2S	2/17/2009	0.004	0				12.16	0.00			1.47
JAV2A2S	3/24/2009		0.09				13.43	0.01			
JAV2A2S	4/21/2009		0.01				10.39	0.00			2.36
JAV2A2S	5/28/2009		0.02				6.47	0.00			
JAV2A2S	6/29/2009	0.12	0.02				6.93	0.00			1.71
JAV2A2S	9/15/2009		0.07				4.52	0.02			
JAV2A2S	11/17/2009		0				23.76	0.00			
JAV2A2S	12/15/2009		0				17.64	0.00			4.29
JAV2A2S	1/19/2010		0				12.07	0.00			
JAV2A2S	2/18/2010	0.02	0				9.38	0.00			2.96
JAV2A2S	3/16/2010		0				7.73	0.00			
JAV2A2S	4/22/2010		0				6.38	0.00			
JAV2A2S	5/18/2010		0.01				8.5	0.00			

Block 2, Transect A, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-a2d	1/12/2005	0.03	0.05	0.1	0.26	0.49						
Jav2-a2d	1/26/2005	0.03	0.05	0.13	0.23	0.37						
Jav2-a2d	2/9/2005	0.02	0.05	0.12	0.24	0.37						
Jav2-a2d	2/23/2005	0.03	0.05	0.05	0.27	0.24						
Jav2-a2d	3/10/2005	0.01	0.05	0.16	0.05	0.22	0.5	1.3	0.12			
Jav2-a2d	3/23/2005	0.005	0.05	6.9	0.17	0.2						
Jav2-a2d	4/6/2005	0.01	0.05	5.8	0.08	0.6	1.3	1.7	3.41			
Jav2-a2d	4/20/2005	0.005	0.05	0.2	0.1	0.44	0.5	0.5	0.40			
Jav2-a2d	5/5/2005	0.01	0.05	0.05	0.1	0.31	0.5	2.3	0.02			
Jav2-a2d	5/18/2005	0.005	0.05	0.12	0.07	0.51	0.5	2.5	0.05			
Jav2-a2d	6/2/2005	0.005	0.05	0.05	0.06	0.35	2.2	3.5	0.01			
Jav2-a2d	6/15/2005	0.005	0.05	0.11	0.04	0.35	0.5	1.8	0.06			
Jav2-a2d	6/29/2005	0.005	0.05	0.24	0.2	1.9	0.5	1.7	0.14			
Jav2-a2d	7/13/2005	0.005	0.05	0.42	0.06	0.35	1.1	1.9	0.22			
Jav2-a2d	7/27/2005	0.005	0.05	0.22			1.3	5	0.04			
Jav2-a2d	8/10/2005	0.005	0.05	0.14			1.1	3.5	0.04			
Jav2-a2d	8/23/2005	0.01	0.05	0.22			0.5	3.5	0.06			
Jav2-a2d	9/29/2005	0.02	0.05	0.23			1.3	3.6	0.06			
Jav2-a2d	10/27/2005	0.02	0.05	0.28			1.3	3.8	0.07			
Jav2-a2d	12/1/2005	0.005	0.05	0.21			0.5	2.1	0.10			
Jav2-a2d	1/12/2006	0.005	0.05	0.19			1.9	2.5	0.08			
Jav2-a2d	2/9/2006	0.005	0.05	0.05			1.5	2.8	0.02			
Jav2-a2d	3/9/2006	0.02	0.05	0.18			1.3	4.3	0.04			

Jav2-a2d	4/13/2006	0.01	0.05	0.11	1.2	5.3	0.02		
Jav2-a2d	5/12/2006	0.005	0.05	0.05	1.9	4.9	0.01		
Jav2-a2d	6/8/2006	0.005	0.05	0.17	0.5	6.5	0.03		
Jav2-a2d	8/10/2006	0.04	0.05	0.11	0.5	2.4	0.05		
JAV2-A2D	9/20/2006	0.03	0.05	0.05	0.5	1.2	0.04		
JAV2-A2D	10/18/2006	0.03	0.05	0.05	0.5	1.2	0.04		
JAV2-A2D	11/21/2006	0.02	0.05	0.11	0.5	0.5	0.22		
JAV2-A2D	12/20/2006	0.02	0.05	0.11	0.5	0.5	0.22		
JAV2-A2D	1/24/2007	0.005	0.05	0.11	0.5	1.5	0.07		
JAV2-A2D	2/21/2007	0.02	0.05	0.13	0.5	0.5	0.07		
JAV2-A2D	4/1/2007	0.02	0.05	0.12	0.5	1.2	0.10		
JAV2-A2D	5/1/2007	0.03	0.2	0.12	0.5	0.5	0.10		
JAV2-A2D	6/1/2007	0.03	0.05	0.13	0.5	0.5	0.10		
JAV2-A2D	7/1/2007	0.03	0.05	0.13	0.5	1	0.13		
JAV2-A2D	8/20/2007	0.02	0.05	0.15	0.5	1.3	0.12		
JAV2-A2D	9/17/2007	0.05	0.05	0.18	0.5	1.3	0.14		
JAV2-A2D	10/24/2007	0.05	0.05	0.17	2.1	1.1	0.14		
JAV2-A2D	11/24/2007	0.03	0.05	0.27	0.5	0.5	0.14		
JAV2-A2D	4/22/2008	0.13	0.01	0.07	4.76	33.67	0.00		
JAV2-A2D	5/13/2008	0.17	0.02	0.1	3.86	4.29	0.02		
JAV2-A2D	6/10/2008	0.13	0.02	0.15	4.01	4.09	0.04		
JAV2-A2D	7/8/2008		0.028	0.13		1.43	0.09		
JAV2-A2D	7/8/2008		0.032	4.22		8.12	0.52		
JAV2A2D	8/6/2008		0.02	0.13		3	0.04		16.16
JAV2-A2D	9/24/2008		0.006	0		2.92	0.00		
JAV2-A2D	10/22/2008		0.00	0.13		3.19	0.04		1.15
JAV2-A2D	11/19/2008		0.008	0.15		4.39	0.03		0.56
JAV2-A2D	12/17/2008		0	0		3.22	0.00		
JAV2-A2D	1/23/2009		0.03	0		17.87	0.00		
JAV2A2D	2/17/2009		0.017	0		8.57	0.00		0.37
JAV2-A2D	1/23/2009		0.03	0		17.87	0.00		
JAV2A2D	2/17/2009		0.017	0		8.57	0.00		0.37
JAV2A2D	3/24/2009			0.19		4.57	0.04		
JAV2A2D	4/21/2009			0.06		2.98	0.02		0.48
JAV2A2D	5/28/2009			0.13		2.47	0.05		
JAV2A2D	6/29/2009		0.06	0.13		3.38	0.04	2.8	1.1
JAV2A2D	7/21/2009			1.18		2.87	0.41		1.63
JAV2A2D	8/18/2009			0.14		3.06	0.05		0.9
JAV2A2D	9/15/2009			0.14		3.16	0.04		
JAV2A2D	10/20/2009		0.02	0.15		3.71	0.04		2.66
JAV2A2D	11/17/2009			0.06		4.05	0.01		
JAV2A2D	12/15/2009			0.12		3.7	0.03		4.13
JAV2A2D	1/19/2010			0.07		2.95	0.02		
JAV2A2D	2/18/2010		0.02	0.15		2.96	0.05		0.52
JAV2A2D	3/16/2010			0.11		2.83	0.04		

JAV2A2D	4/22/2010	0.12	3.48	0.03
JAV2A2D	5/18/2010	0.12	3.18	0.04

Block 2, Transect A, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-a3s	1/12/2005	0.03	0.12	0.05	0.11	0.61						
Jav2-a3s	1/26/2005	0.02	0.05	0.05	0.11	0.48						
Jav2-a3s	2/9/2005	0.005	0.05	0.05	0.005	0.29						
Jav2-a3s	2/23/2005	0.02	0.05	0.14	0.05	0.45						
Jav2-a3s	3/10/2005	0.005	0.05	0.15	0.05	0.73	4	4.5	0.03			
Jav2-a3s	3/23/2005	0.005	0.05	5.9	0.02	0.05						
Jav2-a3s	4/20/2005	0.005	0.13	0.19	0.05	0.48	1.3	3.4	0.06			
Jav2-a3s	5/5/2005	0.005	0.05	0.05	0.04	0.26	4.6	3.4	0.01			
Jav2-a3s	5/5/2005	0.02	0.05	0.05	0.12	0.63	4.1	2	0.03			
Jav2-a3s	4/6/2005	0.005	0.05	0.05	0.07	0.52	4.7	5.5	0.01			
Jav2-a3s	5/18/2005	0.005	0.05	0.05	0.06	0.67	4.4	4.2	0.01			
Jav2-a3s	6/2/2005	0.005	0.05	0.05	0.05	0.54	5.9	5.1	0.01			
Jav2-a3s	6/15/2005	0.005	0.05	0.05	0.01	0.55	4.1	3	0.02			
Jav2-a3s	6/29/2005	0.005	0.05	0.05	0.03	0.35	3.3	3.1	0.02			
Jav2-a3s	7/13/2005	0.005	0.05	0.23	0.15	0.61	3.3	3	0.08			
Jav2-a3s	7/27/2005	0.005	0.05	0.25			7.2	7.9	0.03			
Jav2-a3s	8/10/2005	0.01	0.05	0.05			3.8	5.4	0.01			
Jav2-a3s	8/23/2005	0.02	0.05	2.3			0.5	4.6	0.50			
Jav2-a3s	10/27/2005	0.02	0.05	0.05			2.1	4.3	0.01			
Jav2-a3s	12/1/2005	0.005	0.05	0.05			4.2	1.4	0.04			
Jav2-a3s	1/12/2006	0.005	0.05	0.05			4.5	3.6	0.01			
Jav2-a3s	2/9/2006	0.005	0.05	0.05			6	3.8	0.01			
Jav2-a3s	3/9/2006	0.005	0.05	0.05			9.3	3.3	0.02			
Jav2-a3s	4/13/2006	0.01	0.05	0.1			4.3	3.7	0.03			
Jav2-a3s	5/12/2006	0.005	0.05	0.05			4.2	2	0.03			
Jav2-a3s	6/8/2006	0.005	0.12	0.05			2.5	2.2	0.02			
Jav2-a3s	8/10/2006	0.05	0.35	0.05			4.7	8.8	0.01			
JAV2-A3S	9/20/2006	0.03	0.05	0.05			5.2	1.2	0.04			
JAV2-A3S	10/18/2006	0.04	0.05	0.05			4.7	0.5	0.10			
JAV2-A3S	11/21/2006	0.04	0.05	0.05			7.2	1.1	0.05			
JAV2-A3S	12/20/2006	0.06	0.05	0.05			6.4	0.5	0.10			
JAV2-A3S	1/24/2007	0.02	0.05	0.05			6	2	0.03			
JAV2-A3S	2/21/2007	0.04	0.05	0.05			8	1.2	0.03			
JAV2-A3S	3/21/2007	0.005	0.05	0.05			0.5	4.1	0.03			
JAV2-A3S-(Dup?)	3/21/2007	0.03	0.05	0.05			9.7	0.5	0.03			
JAV2-A3S	4/1/2007	0.01	0.05	0.05			5	1	0.03			
JAV2-A3S	5/1/2007	0.05	0.05	0.05			4	0.5	0.03			

JAV2-A3S	6/1/2007	0.07	0.11	0.05		4	0.5	0.03				
JAV2-A3S	7/1/2007	0.08	0.05	0.21		4.1	1.2	0.18				
JAV2-A3S	8/20/2007	0.1	0.37	0.05		3.1	1.3	0.18				
JAV2-A3S	9/17/2007	0.2	0.17	0.05		3	1.3	0.18				
JAV2-A3S	10/24/2007	0.25	0.1	0.12		4.2	0.5	0.18				
JAV2-A3S	11/24/2007	0.09	0.05	0.27		4.6	0.5	0.18				
JAV2-A3S	4/22/2008	0.07	0.01	0.31		9.1	55.76	0.01				
JAV2-A3S	5/13/2008	0.08	0.02	0.08		8.6	3.04	0.03				
JAV2-A3S	6/10/2008	0.13	0.04	0.03		6.66	6.08	0.00				
JAV2-A3S	7/8/2008		0.016	0.17			1.12	0.15	3.12	6.6		
JAV2A3S	8/6/2008		0.03	0.32			3.37	0.09				20.4
JAV2-A3S	9/24/2008		0.023	1.85			3.68	0.50				
JAV2-A3S	12/17/2008		0	0.4			5.45	0.07				
JAV2-A3S	1/23/2009		0.03	0.25			9.55	0.03				
JAV2A3S	2/17/2009		0.009	0.15			4.3	0.03	3.8	8		2.24
JAV2A3S	3/24/2009			0.42			4.12	0.10	3.14	8.8		
JAV2A3S	4/21/2009			0.1			3.45	0.03	3.62	8.2		3.17
JAV2A3S	5/28/2009			0.07			3.44	0.02				
JAV2A3S	11/17/2009			0.03			6.75	0.00	4.3	8.3		
JAV2A3S	12/15/2009			0.08			6.26	0.01	3.79	5.3		7.81
JAV2A3S	1/19/2010			0.11			5.02	0.02	2.28	5.5		
JAV2A3S	2/18/2010								2.74	5.6		7.26
JAV2A3S	3/16/2010			0.04			4.08	0.01	2.6	4.42		
JAV2A3S	4/22/2010			0.01			3.4	0.00	2.99	0.67		
JAV2A3S	5/18/2010			0.05			3.01	0.02	2.05	0		

Block 2, Transect A, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-a3d	1/12/2005	0.02	0.05	0.26	0.09	0.72						
Jav2-a3d	1/26/2005	0.03	0.05	0.29	0.19	0.48						
Jav2-a3d	2/9/2005	0.01	0.05	0.34	0.09	0.37						
Jav2-a3d	2/23/2005	0.04	0.13	0.38	0.47	1.3						
Jav2-a3d	3/10/2005	0.005	0.05	0.48	0.03	0.51	1.6	1.4	0.34			
Jav2-a3d	3/23/2005	0.005	0.05	1.1	0.07	0.05						
Jav2-a3d	4/6/2005	0.03	0.05	1.1	0.04	0.49	1.8	1.6	0.69			
Jav2-a3d	4/20/2005	0.005	0.05	0.46	0.04	0.48	0.5	0.5	0.92			
Jav2-a3d	5/5/2005	0.01	0.05	0.37	0.05	0.38	0.5	2.8	0.13			
Jav2-a3d	5/18/2005	0.005	0.05	0.52	0.06	0.41	1.6	2.9	0.18			
Jav2-a3d	6/2/2005	0.005	0.05	0.39	0.1	0.39	2.5	3.1	0.13			
Jav2-a3d	6/15/2005	0.005	0.05	0.46	0.13	0.65	0.5	1.9	0.24			
Jav2-a3d	6/29/2005	0.005	0.05	0.44	0.01	0.3	0.5	1.8	0.24			
Jav2-a3d	7/13/2005	0.005	0.05	0.76	0.09	0.21	0.5	1.9	0.40			

Jav2-a3d	7/27/2005	0.07	0.05	0.87	2	5.1	0.17			
Jav2-a3d	8/10/2005	0.01	0.05	0.68	1.3	3.3	0.21			
Jav2-a3d	8/23/2005	0.01	0.05	2.3	0.5	4.2	0.55			
Jav2-a3d	9/29/2005	0.02	0.05	0.74	1.9	3.7	0.20			
Jav2-a3d	10/27/2005	0.03	0.05	0.93	0.5	4	0.23			
Jav2-a3d	12/1/2005	0.005	0.05	0.65	1	1.9	0.34			
Jav2-a3d	1/12/2006	0.01	0.05	0.87	1.4	2.4	0.36			
Jav2-a3d	2/9/2006	0.005	0.05	0.65	0.5	2.1	0.31			
Jav2-a3d	3/9/2006	0.03	0.05	0.69	0.5	3.3	0.21			
Jav2-a3d	4/13/2006	0.02	0.05	0.66	0.5	2.9	0.23			
Jav2-a3d	5/12/2006	0.01	0.05	0.56	0.5	1.8	0.31			
Jav2-a3d	6/8/2006	0.02	0.05	1.1	0.5	2	0.55			
Jav2-a3d	8/10/2006	0.06	0.12	0.74	1.4	1.5	0.49			
JAV2-A3D	9/20/2006	0.15	0.61	0.67	2.6	3.1	0.22			
JAV2-A3D	10/18/2006	0.09	0.05	0.66	1.2	0.5	1.32			
JAV2-A3D	11/21/2006	0.03	0.05	0.73	1.2	0.5	1.46			
JAV2-A3D	12/20/2006	0.04	0.05	0.71	0.5	0.5	1.42			
JAV2-A3D	1/24/2007	0.03	0.05	0.61	0.5	1.4	0.44			
JAV2-A3D	2/21/2007	0.03	0.05	0.58	1	0.5	0.44			
JAV2-A3D	3/21/2007	0.01	0.05	0.15	0.5	0.5	0.44			
JAV2-A3D- (Dup?)	3/21/2007	0.01	0.05	0.56	0.5	0.5	0.44			
JAV2-A3D	4/1/2007	0.77	11.6	0.66	3.2	2.1	0.31			
JAV2-A3D	5/1/2007	0.06	0.05	0.49	1.5	0.5	0.31			
JAV2-A3D	6/1/2007	0.08	0.05	0.62	2.7	0.5	0.31			
JAV2-A3D	7/1/2007	0.04	0.05	0.58	0.5	0.5	0.31			
JAV2-A3D	8/20/2007	0.05	0.14	0.61	0.5	1.3	0.47			
JAV2-A3D	9/17/2007	0.03	0.19	0.72	0.5	1.5	0.48			
JAV2-A3D	10/24/2007	0.07	0.12	0.74	3.3	0.5	0.48			
JAV2-A3D	11/24/2007	0.05	0.05	0.73	1.7	0.5	0.48			
JAV2-A3D	4/22/2008	0.2	0.08	0.58	4.94	72.53	0.01			
JAV2-A3D	5/13/2008	0.24	0.28	2.92	5.51	4.09	0.71			
JAV2-A3D	6/10/2008	0.17	0.05	0.75	5.01	2.82	0.27			
JAV2-A3D	7/8/2008		0.131	0.74		0.97	0.76	5.17	8.7	
JAV2A3D	8/6/2008		0.1	0.7		3.14	0.22			19.05
JAV2-A3D	9/24/2008		0.068	1.19		2.82	0.42			
JAV2-A3D	10/22/2008		0.02	0.76		2.84	0.27			
JAV2-A3D	12/17/2008		0.01	0.71		2.7	0.26			
JAV2-A3D	1/23/2009		0.03	0.62		5.75	0.11			
JAV2A3D	2/17/2009		0.019	0.53		3.15	0.17	5	8.1	0.45
JAV2A3D	3/24/2009			0.74		2.73	0.27	5.02	8.9	
JAV2A3D	4/21/2009			0.59		2.26	0.26			
JAV2A3D	5/28/2009			0.77		2.28	0.34	4.9	7.4	
JAV2A3D	6/29/2009		0.1	0.75		3.82	0.20			
JAV2A3D	7/21/2009			1.07		2.6	0.41			

JAV2A3D	8/18/2009		0.89		3.28	0.27					
JAV2A3D	12/15/2009		0.8		3.73	0.21					
JAV2A3D	1/19/2010		0.7		3.11	0.23	4.54	7.6			
JAV2A3D	2/18/2010	0.03	0.74		2.86	0.26					
JAV2A3D	3/16/2010		0.67		3.1	0.22	4.6	2.15			
JAV2A3D	4/22/2010		0.81		3.23	0.25					
JAV2A3D	5/18/2010		0.74		3.18	0.23					

Block 2, Transect B, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b1s	1/12/2005	0.26	0.1	3.50	0.58	1.2						
Jav2-b1s	1/26/2005	0.1	0.05	3.80	0.41	0.92						
Jav2-b1s	2/9/2005	0.09	0.05	4.20	0.36	1						
Jav2-b1s	2/23/2005	0.11	0.05	4.70	0.53	1.6						
Jav2-b1s	3/10/2005	0.05	0.05	5.10	0.12	0.59	1.5	6	0.85			
Jav2-b1s	3/23/2005	0.02	0.05	4.00	0.11	0.17						
Jav2-b1s	4/6/2005	0.02	0.05	1.70	0.15	0.72	1.4	6.5	0.26			
Jav2-b1s	4/20/2005	0.005	0.05	5.20	0.11	0.55	0.5	8.9	0.58			
Jav2-b1s	5/5/2005	0.005	0.05	5.20	0.1	0.4	1.3	6.3	0.83			
Jav2-b1s	5/18/2005	0.005	0.05	5.20	0.09	0.6	2.5	9.1	0.57			
Jav2-b1s	6/2/2005	0.005	0.05	4.90	0.12	1.1	2	9.6	0.51			
Jav2-b1s	6/15/2005	0.005	0.05	5.20	0.17	1.2	0.5	6.7	0.78			
Jav2-b1s	6/29/2005	0.27	6.3	0.63	0.7	8.2	1.5	6.8	0.09			
Jav2-b1s	7/13/2005	0.005	0.05	3.80	0.47	1.3	1.2	7.1	0.54			
Jav2-b1s	12/1/2005	0.03	0.05	6.60			1.9	6.1	1.08			
Jav2-b1s	1/12/2006	0.05	0.05	4.00			3	7.4	0.54			
Jav2-b1s	2/9/2006	0.005	0.05	4.50			2.7	7.6	0.59			
Jav2-b1s	3/9/2006	0.005	0.05	6.00			2.3	8.6	0.70			
Jav2-b1s	5/12/2006	0.005	0.05	7.40			1.3	8.6	0.86			
Jav2-b1s	6/8/2006	0.005	0.05	6.70			2.1	9.6	0.70			
Jav2-b1s	8/10/2006	0.08	0.14	6.80			2.1	12.6	0.54			
JAV2-B1S	9/20/2006	0.05	0.05	6.90			1.4	7.6	0.91			
JAV2-B1S	10/18/2006	0.06	0.05	7.70			2.7	8.2	0.94			
JAV2-B1S	11/21/2006	0.06	0.05	8.90			1.7	7.3	1.22			
JAV2-B1S	12/20/2006	0.05	0.05	9.70			1.6	8.3	1.17			
JAV2-B1S	1/24/2007	0.03	0.05	9.60			1.5	9.3	1.03			
JAV2-B1S	2/21/2007	0.06	0.05	9.40			1.9	8.3	1.13			
JAV2-B1S	3/21/2007	0.005	0.05	9.30			1.2	7.9	1.18			
JAV2-B1S	4/1/2007	0.05	0.17	10.00			1.3	9.1	1.10			
JAV2-B1S	5/1/2007	0.07	0.14	8.40			1.6	6.7	1.25			
JAV2-B1S	4/22/2008	0.04	0.01	11.15			5.69	24.74	0.45			
JAV2-B1S	5/13/2008	0.04	0.05	23.13			3.52	10.88	2.13			

JAV2-B1S	6/10/2008	0.05	0.39	12.85		5.46	13.93	0.92				
JAV2-B1S	7/8/2008		0.033	12.44			9.88	1.26				
JAV2B1S	8/6/2008		0.84	13.07			13.08	1.00				20.03
JAV2-B1S	12/17/2008		0	13.95			11.33	1.23				
JAV2B1S	3/24/2009			15.26			11.22	1.36	14.06	8.6		
JAV2B1S	4/21/2009			13.72			10.95	1.25	16.06	7.9	1.41	
JAV2B1S	11/17/2009			15.68			10.66	1.47				
JAV2B1S	1/19/2010			16.56			11.56	1.43				
JAV2B1S	2/18/2010		0.02	16.5			11.72	1.41				
JAV2B1S	3/16/2010			16.59			11.96	1.39	16.5	4.24		
JAV2B1S	4/22/2010			16.64			11.69	1.42				
JAV2B1S	5/18/2010			16.2			11.32	1.43				

Block 2, Transect B, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b1d	1/12/2005	0.03	0.05	7.8	0.05	0.5						
Jav2-b1d	1/26/2005	0.005	0.05	7.8	0.03	0.51						
Jav2-b1d	2/9/2005	0.04	0.05	6.2	0.04	0.27						
Jav2-b1d	2/23/2005	0.02	0.05	7.9	0.09	0.3						
Jav2-b1d	3/10/2005	0.02	0.05	8.9	0.24	0.28	1.3	5.2	1.71			
Jav2-b1d	3/23/2005	0.005	0.05	4.6	0.08	0.3						
Jav2-b1d	4/20/2005	0.005	0.05	7.7	0.04	0.34	1.1	0.5	15.40			
Jav2-b1d	5/5/2005	0.005	0.05	7.6	0.02	0.4	0.5	6.9	1.10			
Jav2-b1d	4/6/2005	0.005	0.05	8.1	0.02	0.47	1	7.8	1.04			
Jav2-b1d	5/18/2005	0.005	0.05	8	0.03	0.5	1.2	8.4	0.95			
Jav2-b1d	6/2/2005	0.005	0.05	8.1	0.005	0.54	7	9.1	0.89			
Jav2-b1d	6/15/2005	0.005	0.05	7.8	0.03	0.28	0.5	6.5	1.20			
Jav2-b1d	6/29/2005	0.005	0.05	7.6	0.005	0.41	1.1	6.8	1.12			
Jav2-b1d	7/13/2005	0.005	0.15	6.9	0.05	0.34	1.1	7.3	0.95			
Jav2-b1d	7/27/2005	0.01	0.05	4.9			1.4	11.4	0.43			
Jav2-b1d	8/10/2005	0.005	0.05	6.4			0.5	9.7	0.66			
Jav2-b1d	8/23/2005	0.005	0.05	6.8			0.5	10	0.68			
Jav2-b1d	9/29/2005	0.005	0.05	6.9			0.5	9.8	0.70			
Jav2-b1d	10/27/2005	0.005	0.05	6.4			0.5	9.9	0.65			
Jav2-b1d	12/1/2005	0.02	1.1	3			2.1	12.2	0.25			
Jav2-b1d	1/12/2006	0.005	0.1	7.8			1.8	22.5	0.35			
Jav2-b1d	2/9/2006	0.005	0.05	5.2			2.1	13.6	0.38			
Jav2-b1d	3/9/2006	0.005	0.05	4.9			6.4	11.1	0.44			
Jav2-b1d	4/13/2006	0.005	0.05	4.1			1.7	9.4	0.44			
Jav2-b1d	5/12/2006	0.005	0.05	5.9			1.1	10.5	0.56			
Jav2-b1d	6/8/2006	0.005	0.05	1			1.9	4.4	0.23			
Jav2-b1d	8/10/2006	0.02	0.05	6.1			1.5	10.3	0.59			

JAV2-B1D	9/20/2006	0.01	0.05	5.5	2.1	6.3	0.87		
JAV2-B1D	10/18/2006	0.02	0.05	5.5	3.6	5.5	1.00		
JAV2-B1D	11/21/2006	0.005	0.05	10.6	2	7.8	1.36		
JAV2-B1D	12/20/2006	0.005	0.05	9.3	1.7	7.8	1.19		
JAV2-B1D	1/24/2007	0.005	0.05	10.1	1.8	9	1.12		
JAV2-B1D	2/21/2007	0.005	0.05	8.6	2.1	6.8	1.26		
JAV2-B1D	3/21/2007	0.005	0.05	8.9	1.8	7.2	1.24		
JAV2-B1D	4/1/2007	0.005	0.05	8.2	1.1	6.6	1.24		
JAV2-B1D	5/1/2007	0.1	0.05	8.7	1.7	6.8	1.28		
JAV2-B1D	6/1/2007	0.11	0.15	8.2	1.7	6.5	1.26		
JAV2-B1D	7/1/2007	0.08	0.05	8	1.7	7.6	1.05		
JAV2-B1D	8/20/2007	0.14	0.14	7.7	3.4	8	0.96		
JAV2-B1D	9/17/2007	0.1	0.14	7.3	1.9	8.4	0.87		
JAV2-B1D	10/24/2007	0.23	0.17	6.7	4.3	6.4	0.87		
JAV2-B1D	11/24/2007	0.09	0.17	13.7	2.8	7.1	0.87		
JAV2-B1D	4/22/2008	0.03	0.01	13.97	5.14	14.83	0.94		
JAV2-B1D	5/13/2008	0.04	0.04	23.13	6.43	8.69	2.66		
JAV2-B1D	6/10/2008	0.04	0.02	12.29	5.49	10.8	1.14		
JAV2-B1D	7/8/2008		0.052	8.62		6.7	1.29		
JAV2B1D	8/6/2008		0.04	10.72		9.88	1.09		18.4
JAV2-B1D	9/24/2008		0.41	10.22		10.03	1.02		
JAV2-B1D	10/22/2008		0.04	10.01		9.82	1.02		3.2
JAV2-B1D	11/19/2008		0.003	13.5		11.17	1.21		3.19
JAV2-B1D	12/17/2008		0	21.29		16.8	1.27		
JAV2-B1D	1/23/2009		0.05	16.28		26.11	0.62		
JAV2B1D	2/17/2009		0.001	13.76		9.83	1.40		0.86
JAV2B1D	3/24/2009			22.22		8.72	2.55	5.54	20.8
JAV2B1D	4/21/2009			16.82		8.66	1.94	5.67	18.3
JAV2B1D	5/28/2009			15.13		9.55	1.58	5	10.7
JAV2B1D	6/29/2009		0.05	15.26		10.33	1.48	4.9	9.6
JAV2B1D	7/21/2009			16.57		10.02	1.65	6.2	16
JAV2B1D	8/18/2009			14.65		9.32	1.57	5.3	0.93
JAV2B1D	9/15/2009			15.15		9.13	1.66	5.02	2.7
JAV2B1D	11/17/2009			13.29		7.08	1.88	3.7	13.3
JAV2B1D	12/15/2009			13.45		7.64	1.76	3.85	7.1
JAV2B1D	1/19/2010			12.48		6.28	1.99	2.81	12
JAV2B1D	2/18/2010		0.01	10.59		5.52	1.92	2.97	11.5
JAV2B1D	3/16/2010			11.47		6.42	1.79	3.1	6.81
JAV2B1D	4/22/2010			13.99		6.01	2.33	3.29	8.37
JAV2B1D	5/18/2010			15.44		6.38	2.42	3.2	6.16

Block 2, Transect B, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b2s	1/12/2005	0.02	0.05	2.4	0.07	0.59						
Jav2-b2s	1/26/2005	0.01	0.05	2.9	0.12	0.47						
Jav2-b2s	2/9/2005	0.005	0.05	3.3	0.04	0.4						
Jav2-b2s	2/23/2005	0.01	0.05	3.7	0.05	0.5						
Jav2-b2s	3/10/2005	0.29	0.05	3.3	1.5	2.2	4.8	3.2	1.03			
Jav2-b2s	3/23/2005	0.005	0.26	2.9	0.09	0.52						
Jav2-b2s	4/6/2005	0.05	3	0.36	0.15	3.7	2	4	0.09			
Jav2-b2s	4/20/2005	0.005	0.05	2.7	0.1	0.32	2.4	4.1	0.66			
Jav2-b2s	5/5/2005	0.01	0.05	2.2	0.09	0.93	2.4	1.7	1.29			
Jav2-b2s	5/18/2005	0.005	0.05	1.6	0.26	0.79	2.3	3.7	0.43			
Jav2-b2s	6/2/2005	0.005	0.05	1.3	0.63	1.4	6.9	4.5	0.29			
Jav2-b2s	6/15/2005	0.005	0.05	0.52	0.4	0.88	1.6	2.3	0.23			
Jav2-b2s	6/29/2005	0.01	0.05	0.48	0.33	0.71	1.9	2.2	0.22			
Jav2-b2s	7/13/2005	0.01	0.05	0.68	0.48	0.66	1.8	2.4	0.28			
Jav2-b2s	7/27/2005	0.005	0.05	0.65			2.9	6.3	0.10			
Jav2-b2s	8/10/2005	0.02	0.05	0.64			2.5	4.3	0.15			
Jav2-b2s	8/23/2005	0.02	0.05	0.88			2.2	4.4	0.20			
Jav2-b2s	9/29/2005	0.02	0.05	1.3			1.8	4.5	0.29			
Jav2-b2s	10/27/2005	0.02	0.05	1.3			1.7	4.6	0.28			
Jav2-b2s	12/1/2005	0.005	0.05	1.8			2.2	2.8	0.64			
Jav2-b2s	1/12/2006	0.005	0.05	5.1			3	12.3	0.41			
Jav2-b2s	2/9/2006	0.005	0.05	4.3			3.5	12	0.36			
Jav2-b2s	3/9/2006	0.01	0.11	1.7			3.2	9.3	0.18			
Jav2-b2s	4/13/2006	0.01	0.05	1.1			1.3	4.5	0.24			
Jav2-b2s	5/12/2006	0.005	0.05	1.5			1.5	2.9	0.52			
Jav2-b2s	6/8/2006	0.005	0.13	0.69			1.3	4	0.17			
Jav2-b2s	8/10/2006	0.05	0.12	0.51			3.3	4.8	0.11			
JAV2-B2S	9/20/2006	0.07	0.05	0.05			3.3	2.7	0.02			
JAV2-B2S	10/18/2006	0.05	0.05	0.17			3.7	3.7	0.05			
JAV2-B2S	11/21/2006	0.05	0.05	0.72			4.5	2.5	0.29			
JAV2-B2S	12/20/2006	0.05	0.05	1.5			3.3	2.6	0.58			
JAV2-B2S	1/24/2007	0.02	0.05	1.9			2	3.7	0.51			
JAV2-B2S	2/21/2007	0.05	0.05	2.6			3	2.6	1.00			
JAV2-B2S	3/21/2007	0.03	0.05	2			2.6	2.7	0.74			
JAV2-B2S	4/1/2007	0.04	0.05	0.55			2	3.3	0.17			
JAV2-B2S	5/1/2007	0.12	0.05	0.58			2.4	1.1	0.53			
JAV2-B2S	6/1/2007	0.21	0.05	0.63			2.8	0.5	0.53			
JAV2-B2S	7/1/2007	0.09	0.05	2.2			2.2	2.3	0.96			
JAV2-B2S	8/20/2007	0.07	0.05	2.3			1.7	2.4	0.96			
JAV2-B2S	9/17/2007	0.05	0.05	3.2			1.5	3.4	0.94			
JAV2-B2S	10/24/2007	0.1	0.05	3.9			3.7	3.3	0.94			

JAV2-B2S	11/24/2007	0.1	0.05	1.8		3.1	2.2	0.94				
JAV2-B2S	4/22/2008	0.08	0.01	0.3		4.94	33.22	0.01				
JAV2-B2S	5/13/2008	0.08	0.02	0.32		5.54	3.86	0.08				
JAV2-B2S	6/10/2008	0.11	0.00	0.8		5.12	3.65	0.22				
JAV2-B2S	7/8/2008		0.01	1.56			1.96	0.80				
JAV2B2S	8/6/2008		0.02	2.64			4.71	0.56				17.14
JAV2-B2S	9/24/2008		0.121	3.61			6.33	0.57				
JAV2-B2S	10/22/2008		0.01	4.44			7.25	0.61				0
JAV2-B2S	11/19/2008		0.025	5.15			9.49	0.54				1.11
JAV2-B2S	1/23/2009		0.03	1.57			26.56	0.06				
JAV2B2S	3/24/2009			2			5.76	0.35				
JAV2B2S	4/21/2009			2.36			4.55	0.52				1.79
JAV2B2S	5/28/2009			2.42			3.63	0.67				
JAV2B2S	6/29/2009		0.04	2.55			5.32	0.48	3.9	3.5		1.5
JAV2B2S	7/21/2009			3.46			4.72	0.73				
JAV2B2S	8/18/2009			4.96			5.97	0.83	4	0.66		1.33
JAV2B2S	9/15/2009			7.26			7.86	0.92				
JAV2B2S	10/20/2009		0.02	7.17			8.97	0.80				4.52
JAV2B2S	11/17/2009			4.19			10.82	0.39				
JAV2B2S	12/15/2009			1.89			6.71	0.28				5.71
JAV2B2S	1/19/2010			3.08			4.94	0.62				
JAV2B2S	2/18/2010		0.02	3.87			10.34	0.37				5.19
JAV2B2S	3/16/2010			2.08			4.08	0.51				
JAV2B2S	4/22/2010			2.11			3.93	0.54				
JAV2B2S	5/18/2010			1.6			4.64	0.34				

Block 2, Transect B, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b2s	1/12/2005	0.02	0.05	2.4	0.07	0.59						
Jav2-b2s	1/26/2005	0.01	0.05	2.9	0.12	0.47						
Jav2-b2s	2/9/2005	0.005	0.05	3.3	0.04	0.4						
Jav2-b2s	2/23/2005	0.01	0.05	3.7	0.05	0.5						
Jav2-b2s	3/10/2005	0.29	0.05	3.3	1.5	2.2	4.8	3.2	1.03			
Jav2-b2s	3/23/2005	0.005	0.26	2.9	0.09	0.52						
Jav2-b2s	4/6/2005	0.05	3	0.36	0.15	3.7	2	4	0.09			
Jav2-b2s	4/20/2005	0.005	0.05	2.7	0.1	0.32	2.4	4.1	0.66			
Jav2-b2s	5/5/2005	0.01	0.05	2.2	0.09	0.93	2.4	1.7	1.29			
Jav2-b2s	5/18/2005	0.005	0.05	1.6	0.26	0.79	2.3	3.7	0.43			
Jav2-b2s	6/2/2005	0.005	0.05	1.3	0.63	1.4	6.9	4.5	0.29			
Jav2-b2s	6/15/2005	0.005	0.05	0.52	0.4	0.88	1.6	2.3	0.23			
Jav2-b2s	6/29/2005	0.01	0.05	0.48	0.33	0.71	1.9	2.2	0.22			
Jav2-b2s	7/13/2005	0.01	0.05	0.68	0.48	0.66	1.8	2.4	0.28			
Jav2-b2s	7/27/2005	0.005	0.05	0.65			2.9	6.3	0.10			

Jav2-b2s	8/10/2005	0.02	0.05	0.64	2.5	4.3	0.15			
Jav2-b2s	8/23/2005	0.02	0.05	0.88	2.2	4.4	0.20			
Jav2-b2s	9/29/2005	0.02	0.05	1.3	1.8	4.5	0.29			
Jav2-b2s	10/27/2005	0.02	0.05	1.3	1.7	4.6	0.28			
Jav2-b2s	12/1/2005	0.005	0.05	1.8	2.2	2.8	0.64			
Jav2-b2s	1/12/2006	0.005	0.05	5.1	3	12.3	0.41			
Jav2-b2s	2/9/2006	0.005	0.05	4.3	3.5	12	0.36			
Jav2-b2s	3/9/2006	0.01	0.11	1.7	3.2	9.3	0.18			
Jav2-b2s	4/13/2006	0.01	0.05	1.1	1.3	4.5	0.24			
Jav2-b2s	5/12/2006	0.005	0.05	1.5	1.5	2.9	0.52			
Jav2-b2s	6/8/2006	0.005	0.13	0.69	1.3	4	0.17			
Jav2-b2s	8/10/2006	0.05	0.12	0.51	3.3	4.8	0.11			
JAV2-B2S	9/20/2006	0.07	0.05	0.05	3.3	2.7	0.02			
JAV2-B2S	10/18/2006	0.05	0.05	0.17	3.7	3.7	0.05			
JAV2-B2S	11/21/2006	0.05	0.05	0.72	4.5	2.5	0.29			
JAV2-B2S	12/20/2006	0.05	0.05	1.5	3.3	2.6	0.58			
JAV2-B2S	1/24/2007	0.02	0.05	1.9	2	3.7	0.51			
JAV2-B2S	2/21/2007	0.05	0.05	2.6	3	2.6	1.00			
JAV2-B2S	3/21/2007	0.03	0.05	2	2.6	2.7	0.74			
JAV2-B2S	4/1/2007	0.04	0.05	0.55	2	3.3	0.17			
JAV2-B2S	5/1/2007	0.12	0.05	0.58	2.4	1.1	0.53			
JAV2-B2S	6/1/2007	0.21	0.05	0.63	2.8	0.5	0.53			
JAV2-B2S	7/1/2007	0.09	0.05	2.2	2.2	2.3	0.96			
JAV2-B2S	8/20/2007	0.07	0.05	2.3	1.7	2.4	0.96			
JAV2-B2S	9/17/2007	0.05	0.05	3.2	1.5	3.4	0.94			
JAV2-B2S	10/24/2007	0.1	0.05	3.9	3.7	3.3	0.94			
JAV2-B2S	11/24/2007	0.1	0.05	1.8	3.1	2.2	0.94			
JAV2-B2S	4/22/2008	0.08	0.01	0.3	4.94	33.22	0.01			
JAV2-B2S	5/13/2008	0.08	0.02	0.32	5.54	3.86	0.08			
JAV2-B2S	6/10/2008	0.11	0.00	0.8	5.12	3.65	0.22			
JAV2-B2S	7/8/2008		0.01	1.56		1.96	0.80			
JAV2B2S	8/6/2008		0.02	2.64		4.71	0.56			17.14
JAV2-B2S	9/24/2008		0.121	3.61		6.33	0.57			
JAV2-B2S	10/22/2008		0.01	4.44		7.25	0.61			0
JAV2-B2S	11/19/2008		0.025	5.15		9.49	0.54			1.11
JAV2-B2S	1/23/2009		0.03	1.57		26.56	0.06			
JAV2B2S	3/24/2009			2		5.76	0.35			
JAV2B2S	4/21/2009			2.36		4.55	0.52			1.79
JAV2B2S	5/28/2009			2.42		3.63	0.67			
JAV2B2S	6/29/2009		0.04	2.55		5.32	0.48	3.9	3.5	1.5
JAV2B2S	7/21/2009			3.46		4.72	0.73			
JAV2B2S	8/18/2009			4.96		5.97	0.83	4	0.66	1.33
JAV2B2S	9/15/2009			7.26		7.86	0.92			
JAV2B2S	10/20/2009		0.02	7.17		8.97	0.80			4.52
JAV2B2S	11/17/2009			4.19		10.82	0.39			

JAV2B2S	12/15/2009		1.89		6.71	0.28					5.71
JAV2B2S	1/19/2010		3.08		4.94	0.62					
JAV2B2S	2/18/2010	0.02	3.87		10.34	0.37					5.19
JAV2B2S	3/16/2010		2.08		4.08	0.51					
JAV2B2S	4/22/2010		2.11		3.93	0.54					
JAV2B2S	5/18/2010		1.6		4.64	0.34					

Block 2, Transect B, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b2d	1/12/2005	0.03	0.05	0.26	0.21	0.74						
Jav2-b2d	1/26/2005	0.02	0.05	0.3	0.18	1.1						
Jav2-b2d	2/9/2005	0.005	0.05	0.36	0.02	0.28						
Jav2-b2d	2/23/2005	0.04	0.05	0.34	0.39	0.67						
Jav2-b2d	3/10/2005	0.02	0.05	0.5	0.15	0.52	0.5	1.3	0.38			
Jav2-b2d	3/23/2005	0.005	0.05	0.46	0.2	0.12						
Jav2-b2d	4/6/2005	0.01	0.05	0.45	0.19	0.31	1.2	1.8	0.25			
Jav2-b2d	4/20/2005	0.005	0.05	0.4	0.02	0.22	0.5	0.5	0.80			
Jav2-b2d	5/5/2005	0.01	0.05	0.46	0.19	0.3	1.1	2	0.23			
Jav2-b2d	5/18/2005	0.005	0.05	0.42	0.44	0.44	2.3	2.6	0.16			
Jav2-b2d	6/2/2005	0.01	0.05	0.39	0.15	0.44	2.3	3.4	0.11			
Jav2-b2d	6/15/2005	0.005	0.05	0.33	0.05	0.55	0.5	1.9	0.17			
Jav2-b2d	6/29/2005	0.005	0.05	0.32	0.14	0.32	1	2.1	0.15			
Jav2-b2d	7/13/2005	0.005	0.05	0.64	0.1	0.27	0.5	2.1	0.30			
Jav2-b2d	7/27/2005	0.005	0.05	0.48			1.8	5.5	0.09			
Jav2-b2d	8/10/2005	0.005	0.05	0.41			1.4	3.7	0.11			
Jav2-b2d	8/23/2005	0.01	0.05	0.48			1.9	3.7	0.13			
Jav2-b2d	9/29/2005	0.02	0.05	0.82			2	4.1	0.20			
Jav2-b2d	10/27/2005	0.02	0.05	1.2			2.1	4.7	0.26			
Jav2-b2d	12/1/2005	0.005	0.05	1.8			1.8	2.8	0.64			
Jav2-b2d	1/12/2006	0.005	0.05	0.75			2	2.6	0.29			
Jav2-b2d	2/9/2006	0.005	0.05	0.99			1.4	2.9	0.34			
Jav2-b2d	3/9/2006	0.02	0.05	0.62			1.2	3.4	0.18			
Jav2-b2d	4/13/2006	0.005	0.05	0.55			3.9	2.2	0.25			
Jav2-b2d	5/12/2006	0.005	0.05	0.74			0.5	2.2	0.34			
Jav2-b2d	6/8/2006	0.01	0.05	0.05			1.1	1.3	0.04			
Jav2-b2d	8/10/2006	0.02	0.1	0.44			1.4	3.6	0.12			
JAV2-B2D	9/20/2006	0.02	0.05	0.27			0.5	1.2	0.23			
JAV2-B2D	10/18/2006	0.02	0.05	0.35			2.3	1	0.35			
JAV2-B2D	11/21/2006	0.02	0.05	0.36			1.1	0.5	0.72			
JAV2-B2D	12/20/2006	0.01	0.05	0.32			0.5	0.5	0.64			
JAV2-B2D	1/24/2007	0.005	0.05	0.41			0.5	1.5	0.27			
JAV2-B2D	2/21/2007	0.01	0.05	0.57			1.2	0.5	0.27			
JAV2-B2D	3/21/2007	0.01	0.05	0.6			1.1	1.1	0.55			

JAV2-B2D	4/1/2007	0.02	0.05	0.4			0.5	1.3	0.31			
JAV2-B2D	5/1/2007	0.03	0.05	0.42			0.5	0.5	0.31			
JAV2-B2D	6/1/2007	0.02	0.05	0.5			1.1	1	0.50			
JAV2-B2D	7/1/2007	0.02	0.05	0.88			1	1.5	0.59			
JAV2-B2D	8/20/2007	0.04	0.05	1.2			1.4	2.1	0.57			
JAV2-B2D	9/17/2007	0.04	0.05	2			1.6	2.3	0.87			
JAV2-B2D	10/24/2007	0.04	0.05	2.8			2.6	2.5	0.87			
JAV2-B2D	11/24/2007	0.04	0.05	1.2			2.5	4.1	0.87			
JAV2-B2D	4/22/2008	0.12	0.01	1			3.42	46.47	0.02			
JAV2-B2D	5/13/2008	0.12	0.01	1.86			2.92	3.29	0.57			
JAV2-B2D	6/10/2008	0.11	0.00	0.81			4.42	3.44	0.24			
JAV2-B2D	7/8/2008		0.014	0.77				1.03	0.75			
JAV2B2D	8/6/2008		0.03	0.75				2.9	0.26			16.8
JAV2-B2D	9/24/2008		0.005	2.46				4.96	0.50			
JAV2-B2D	10/22/2008		0.00	3.59				5.8	0.62			0
JAV2-B2D	11/19/2008		0.008	4.95				8.74	0.57			1.43
JAV2-B2D	12/17/2008		0	3.51				5.31	0.66			
JAV2-B2D	12/17/2008		0	3.93				5.56	0.71			
JAV2-B2D	1/23/2009		0.02	2.65				10.73	0.25			
JAV2B2D	2/17/2009		0.001	1.89				4.69	0.40			0.73
JAV2B2D	3/24/2009			1.6				3.07	0.52			
JAV2B2D	4/21/2009			1.01				2.75	0.37			0.53
JAV2B2D	5/28/2009			0.86				2.41	0.36			
JAV2B2D	6/29/2009		0.09	0.99				4.15	0.24	3.6	2.4	0.97
JAV2B2D	7/21/2009			1.78				3.64	0.49			
JAV2B2D	8/18/2009			4.35				5.78	0.75	4.8	0.54	1.46
JAV2B2D	9/15/2009			5.28				6.48	0.81			
JAV2B2D	10/20/2009		0.04	4.3				6.92	0.62			5.27
JAV2B2D	11/17/2009			5.12				5.81	0.88			
JAV2B2D	12/15/2009			3.25				5.67	0.57			3.51
JAV2B2D	1/19/2010			1.89				3.85	0.49			
JAV2B2D	2/18/2010		0.02	1.24				3.48	0.36			1.59
JAV2B2D	3/16/2010			1				3.28	0.30			
JAV2B2D	4/22/2010			0.77				2.85	0.27			
JAV2B2D	5/18/2010			0.7				3.54	0.20			

Block 2, Transect B, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b3s	1/12/2005	0.04	0.05	4.9	0.39	0.6						
Jav2-b3s	1/26/2005	0.03	0.05	5.1	0.35	0.71						
Jav2-b3s	2/9/2005	0.005	0.05	4.6	0.1	0.39						
Jav2-b3s	2/23/2005	0.03	0.05	4.9	0.17	0.76						

Jav2-b3s	3/10/2005	0.04	0.05	4.2	0.43	1	2.8	3.1	1.35				
Jav2-b3s	3/23/2005	0.005	0.05	0.39	0.16	0.33							
Jav2-b3s	4/6/2005	0.005	0.05	0.05	0.11	0.44	3.7	2.5	0.02				
Jav2-b3s	4/20/2005	0.005	0.05	2.5	0.07	0.42	2.9	4	0.63				
Jav2-b3s	5/5/2005	0.005	0.05	3.3	0.1	0.39	1.8	3.6	0.92				
Jav2-b3s	5/18/2005	0.005	0.05	4.3	0.06	0.5	2.4	6.1	0.70				
Jav2-b3s	6/2/2005	0.005	0.05	4	0.14	0.67	1.7	6	0.67				
Jav2-b3s	6/15/2005	0.005	0.05	4	0.07	0.63	1	4.3	0.93				
Jav2-b3s	6/29/2005	0.005	0.05	4.7	0.08	0.39	1	4.4	1.07				
Jav2-b3s	7/13/2005	0.005	0.05	4.2	0.07	0.5	1.2	4.6	0.91				
Jav2-b3s	7/27/2005	0.005	0.05	4.2			1.6	7.5	0.56				
Jav2-b3s	8/10/2005	0.005	0.05	3.4			1	6.2	0.55				
Jav2-b3s	8/23/2005	0.01	0.05	3.1			1.4	6	0.52				
Jav2-b3s	9/29/2005	0.01	0.05	3.1			1.2	6	0.52				
Jav2-b3s	10/27/2005	0.01	0.05	3.4			1.2	6.2	0.55				
Jav2-b3s	12/1/2005	0.005	0.05	3.4			2.9	4.2	0.81				
Jav2-b3s	1/12/2006	0.005	0.05	2.8			2.2	4.5	0.62				
Jav2-b3s	2/9/2006	0.005	0.05	4			2.7	4.3	0.93				
Jav2-b3s	3/9/2006	0.05	0.05	4.1			1.8	5.6	0.73				
Jav2-b3s	4/13/2006	0.005	0.05	3.2			0.5	4.7	0.68				
Jav2-b3s	5/12/2006	0.005	0.05	3			2.1	3.6	0.83				
Jav2-b3s	6/8/2006	0.005	0.05	2.5			0.5	3.7	0.68				
Jav2-b3s	8/10/2006	0.04	0.05	2.5			2	3.9	0.64				
JAV2-B3S	9/20/2006	0.05	0.05	1.7			1.4	2.8	0.61				
JAV2-B3S	10/18/2006	0.05	0.05	2.1			2.1	2.4	0.88				
JAV2-B3S	11/21/2006	0.03	0.05	3.5			2.2	2.4	1.46				
JAV2-B3S	12/20/2006	0.09	0.05	4.8			2.1	2.7	1.78				
JAV2-B3S	1/24/2007	0.02	0.05	2.4			3.3	4.3	0.56				
JAV2-B3S	2/21/2007	0.03	0.05	3.4			3.3	3.6	0.94				
JAV2-B3S	3/21/2007	0.02	0.05	3.4			2.6	3.8	0.89				
JAV2-B3S	4/1/2007	0.01	0.05	4.7			1.3	4.3	1.09				
JAV2-B3S	5/1/2007	0.02	0.05	4			1.1	3	1.33				
JAV2-B3S	6/1/2007	0.03	0.05	4.1			1.7	2.7	1.52				
JAV2-B3S	7/1/2007	0.04	0.05	3.6			1.3	3.3	1.09				
JAV2-B3S	8/20/2007	0.07	0.05	2.5			1.3	2.6	0.96				
JAV2-B3S	9/17/2007	0.04	0.05	2.4			1.6	2.4	1.00				
JAV2-B3S	10/24/2007	0.04	0.05	2.5			2.3	2	1.25				
JAV2-B3S	11/24/2007	0.02	0.05	2.8			2	1.9	1.47				
JAV2-B3S	4/22/2008	0.07	0.01	1.61			7.38	42.03	0.04				
JAV2-B3S	5/13/2008	0.07	0.03	2.17			6.46	6.2	0.35				
JAV2-B3S	6/10/2008	0.06	0.00	2.45			6.09	6.83	0.36				
JAV2-B3S	7/8/2008		0.009	2.72				3.35	0.81	2.98	4.7		
JAV2B3S	8/6/2008		0.03	2.53				4.98	0.51				18.77
JAV2-B3S	9/24/2008		0	2.58				4.76	0.54				

JAV2-B3S	10/22/2008	0.00	2.53		4.2	0.60					0.18
JAV2-B3S	11/19/2008	0.017	4.41		3.82	1.15	3.99	6.8			2.28
JAV2-B3S	12/17/2008	0	4.85		5.41	0.90					
JAV2-B3S	1/23/2009	0.02	2.97		21.07	0.14					
JAV2B3S	2/17/2009	0.004	2.87		7.83	0.37	4.5	5.6			1.23
JAV2B3S	3/24/2009		6.73		7.95	0.85	4.7	7.1			
JAV2B3S	4/21/2009		3.97		7.33	0.54	4.19	7.4			1.97
JAV2B3S	5/28/2009		3.37		5.11	0.66	3.3	2.8			
JAV2B3S	6/29/2009	0.03	2.52		4.54	0.56	3.2	1			1.38
JAV2B3S	7/21/2009		2.08		4.12	0.50	3.9	4.6			
JAV2B3S	8/18/2009		1.98		4.26	0.46	3.6	0.18			1.22
JAV2B3S	9/15/2009		2.25		4.71	0.48	4.01	0.8			
JAV2B3S	10/20/2009	0.02	2.33		5.24	0.44	4.5	0			4.9
JAV2B3S	11/17/2009		3.06		4.09	0.75	4.5	3.8			
JAV2B3S	12/15/2009		5.46		8.7	0.63	5.84	1.45			6.36
JAV2B3S	1/19/2010		7.63		17.75	0.43	5.23	11.4			
JAV2B3S	3/16/2010		7.68		10.68	0.72	6.1	4.84			
JAV2B3S	4/22/2010		6.3		7.8	0.81	5.3	4.94			
JAV2B3S	5/18/2010		6.74		7.66	0.88	4.79	1.64			

Block 2, Transect B, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-b3d	1/12/2005	0.04	0.05	0.35	0.17	0.32						
Jav2-b3d	1/26/2005	0.04	0.05	0.44	0.22	0.29						
Jav2-b3d	2/9/2005	0.03	0.05	0.56	0.1	0.29						
Jav2-b3d	2/23/2005	0.04	0.05	0.66	0.24	0.58						
Jav2-b3d	3/10/2005	0.03	0.05	0.85	0.06	0.14	0.5	1.7	0.50			
Jav2-b3d	3/23/2005	0.005	0.05	2.2	0.09	0.21						
Jav2-b3d	4/20/2005	0.005	0.05	0.71	0.11	0.59	0.5	3	0.24			
Jav2-b3d	5/5/2005	0.01	0.05	0.73	0.07	0.29	1	1.7	0.43			
Jav2-b3d	4/6/2005	0.005	0.05	0.63	0.03	0.49	0.5	2.2	0.29			
Jav2-b3d	5/18/2005	0.005	0.05	0.87	0.08	0.4	1.6	3.8	0.23			
Jav2-b3d	6/2/2005	0.09	0.05	0.83	0.13	0.3	0.5	3	0.28			
Jav2-b3d	6/15/2005	0.005	0.05	0.73	0.005	0.56	0.5	2.3	0.32			
Jav2-b3d	6/29/2005	0.005	0.05	0.79	0.05	0.32	0.5	2.3	0.34			
Jav2-b3d	7/13/2005	0.02	0.05	1.1	0.02	0.19	0.5	2.3	0.48			
Jav2-b3d	7/27/2005	0.04	0.05	1.4			1.2	5.9	0.24			
Jav2-b3d	8/10/2005	0.02	0.05	0.97			0.5	4	0.24			
Jav2-b3d	8/23/2005	0.01	0.05	0.9			0.5	4	0.23			
Jav2-b3d	9/29/2005	0.04	0.05	1.1			0.5	4.2	0.26			
Jav2-b3d	10/27/2005	0.02	0.05	0.97			1.3	4.2	0.23			
Jav2-b3d	12/1/2005	0.02	0.05	0.05			0.5	2.2	0.02			

Jav2-b3d	1/12/2006	0.005	0.05	0.91	0.5	2.3	0.40			
Jav2-b3d	2/9/2006	0.02	0.05	1.6	0.5	2.2	0.73			
Jav2-b3d	3/9/2006	0.05	0.05	0.91	1.6	4.4	0.21			
Jav2-b3d	4/13/2006	0.005	0.05	1	0.5	2.1	0.48			
Jav2-b3d	5/12/2006	0.02	0.05	1	0.5	2	0.50			
Jav2-b3d	6/8/2006	0.05	0.29	0.97	0.5	2.2	0.44			
Jav2-b3d	8/10/2006	0.07	0.05	1.2	1.3	2.1	0.57			
JAV2-B3D	9/20/2006	0.04	0.05	0.74	0.5	1.5	0.49			
JAV2-B3D	10/18/2006	0.04	0.05	0.82	1.6	1.2	0.68			
JAV2-B3D	11/21/2006	0.04	0.05	0.86	1.1	1	0.86			
JAV2-B3D	12/20/2006	0.04	0.05	0.89	0.5	0.5	1.78			
JAV2-B3D	1/24/2007	0.04	0.05	0.83	0.5	1.6	0.52			
JAV2-B3D	2/21/2007	0.04	0.05	0.87	0.5	1.1	0.79			
JAV2-B3D	3/21/2007	0.03	0.05	0.83	1	1	0.83			
JAV2-B3D	4/1/2007	0.04	0.05	0.84	0.5	1.4	0.60			
JAV2-B3D	5/1/2007	0.05	0.05	0.88	0.5	1	0.88			
JAV2-B3D	6/1/2007	0.05	0.05	0.97	1.2	0.5	0.88			
JAV2-B3D	7/1/2007	0.04	0.05	1	0.5	1.3	0.77			
JAV2-B3D	8/20/2007	0.04	0.05	1	0.5	1.6	0.63			
JAV2-B3D	9/17/2007	0.04	0.05	1.2	0.5	1.8	0.67			
JAV2-B3D	10/24/2007	0.03	0.05	1.1	2	1.8	0.67			
JAV2-B3D	11/24/2007	0.04	0.05	1.1	1.3	0.5	0.67			
JAV2-B3D	4/22/2008	0.2	0.01	0.76	5.37	32.81	0.02			
JAV2-B3D	5/13/2008	0.2	0.02	1.24	3.45	2.93	0.42			
JAV2-B3D	6/10/2008	0.19	0.02	0.93	4.3	3.05	0.30			
JAV2-B3D	7/8/2008		0.023	1.21		1.14	1.06	6.12	9.2	
JAV2B3D	8/6/2008		0.03	1.01		2.83	0.36			19.12
JAV2-B3D	9/24/2008		0	1.11		3.15	0.35			
JAV2-B3D	10/22/2008		0.00	1.13		2.86	0.40			0
JAV2-B3D	11/19/2008		0.01	1.07		1.52	0.70	6.16	11.5	1.06
JAV2-B3D	12/17/2008		0	0.82		3.1	0.26			
JAV2-B3D	1/23/2009		0.03	0.88		5.91	0.15			
JAV2B3D	2/17/2009		0.002	0.79		2.61	0.30	5.8	10.6	0.31
JAV2B3D	3/24/2009			0.99		2.46	0.40	6.04	11.5	
JAV2B3D	4/21/2009			0.73		2.54	0.29	6.42	11.5	0.56
JAV2B3D	5/28/2009			0.93		2.31	0.40	6	7.7	
JAV2B3D	6/29/2009		0.03	1.06		3.96	0.27	6.1	7.6	1.3
JAV2B3D	7/21/2009			1.22		2.76	0.44	6.9	13.3	
JAV2B3D	8/18/2009			1.1		3.06	0.36	5.8	0.88	0.83
JAV2B3D	9/15/2009			1.07		3.55	0.30	5.84	2.4	
JAV2B3D	10/20/2009		0.08	1.13		4.08	0.28	6.4	1.7	3.47
JAV2B3D	11/17/2009			1.08		2.25	0.48	6	10.8	
JAV2B3D	12/15/2009			0.96		3.62	0.27	6.27	2.8	4.37
JAV2B3D	1/19/2010			0.85		2.79	0.30	5.29	9.7	
JAV2B3D	2/18/2010		0.02	0.87		2.89	0.30	6.04	10	1.31

JAV2B3D	3/16/2010		0.8		2.89	0.28	6.1	3.26
JAV2B3D	4/22/2010		0.83		2.75	0.30	3.58	1.2
JAV2B3D	5/18/2010		0.89		3.83	0.23	6.04	1.34

Block 2, Transect C, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-c1s	1/12/2005	0.02	0.05	4.40	0.1	0.69						
Jav2-c1s	1/26/2005	0.005	0.05	4.40	0.13	0.92						
Jav2-c1s	2/9/2005	0.005	0.05	6.40	0.03	0.38						
Jav2-c1s	2/23/2005	0.01	0.05	6.60	0.08	0.55						
Jav2-c1s	3/10/2005	0.005	0.05	6.50	0.14	0.24	1.1	1.9	3.42			
Jav2-c1s	3/23/2005	0.005	0.05	5.70	0.04	0.05						
Jav2-c1s	4/6/2005	0.02	0.05	0.05	0.09	0.21	1.2	2.7	0.02			
Jav2-c1s	4/20/2005	0.005	0.05	6.90	0.09	0.34	1	4.3	1.60			
Jav2-c1s	5/5/2005	0.005	0.05	6.50	0.1	0.4	1.3	1.8	3.61			
Jav2-c1s	5/18/2005	0.005	0.05	6.80	0.04	0.56	1.4	4.3	1.58			
Jav2-c1s	6/2/2005	0.005	0.05	6.60	0.07	0.54	1.6	4.4	1.50			
Jav2-c1s	6/15/2005	0.005	0.05	6.30	0.06	0.39	0.5	3.1	2.03			
Jav2-c1s	6/29/2005	0.005	0.05	6.30	0.46	0.76	1.1	3	2.10			
Jav2-c1s	7/13/2005	0.005	0.05	5.70	1.1	1.9	1	3.1	1.84			
Jav2-c1s	12/1/2005	0.005	0.05	3.60			4	4.9	0.73			
Jav2-c1s	1/12/2006	0.005	0.05	18.30			2.5	32.4	0.56			
Jav2-c1s	2/9/2006	0.005	0.05	16.20			2.8	27	0.60			
Jav2-c1s	3/9/2006	0.005	0.05	16.20			3.2	25.7	0.63			
Jav2-c1s	4/13/2006	0.005	1.2	15.60			2.6	26.9	0.58			
Jav2-c1s	5/12/2006	0.005	0.24	15.80			1.9	26.1	0.61			
Jav2-c1s	6/8/2006	0.005	0.45	10.70			2.9	22.4	0.48			
Jav2-c1s	8/10/2006	0.06	0.18	6.00			3.9	28.4	0.21			
JAV2-C1S	9/20/2006	0.04	0.05	3.90			3.4	10.5	0.37			
JAV2-C1S	10/18/2006	0.03	0.05	2.20			3.9	8.7	0.25			
JAV2-C1S	11/21/2006	0.03	0.05	14.20			3.1	6.5	2.18			
JAV2-C1S	12/20/2006	0.04	0.05	11.60			2.4	4.8	2.42			
JAV2-C1S	1/24/2007	0.01	0.05	13.40			2.5	8.4	1.60			
JAV2-C1S	2/21/2007	0.05	0.2	11.50			2.9	6.7	1.72			
JAV2-C1S	3/21/2007	0.02	0.05	9.90			2.4	6.4	1.55			
JAV2-C1S	5/1/2007	0.15	0.27	10.60			4.3	4.9	2.16			
JAV2-C1S	4/22/2008	0.08	0.07	12.80			5.4	154	0.08			
JAV2-C1S	5/13/2008	0.04	0.04	13.27			5.37	6.35	2.09			
JAV2-C1S	7/8/2008		0.024	9.65				4.53	2.13			
JAV2-C1S	12/17/2008		0	12.02				6.05	1.99			
JAV2-C1S	1/23/2009		0.06	14.19				26.89	0.53			
JAV2C1S	3/24/2009			16.08				6.93	2.32	7.6	19.1	

JAV2C1S	4/21/2009		12.84		6.67	1.93	6.73	17	3.07
JAV2C1S	11/17/2009		12.5		5.67	2.20	8.3	13.5	
JAV2C1S	12/15/2009		12.05		7.96	1.51	6.08	8.1	6.05
JAV2C1S	1/19/2010		10.06		6.55	1.54	4.64	13.3	
JAV2C1S	2/18/2010	0.02	9.34		5.89	1.59	4.57	13	3.34
JAV2C1S	3/16/2010		9.19		5.78	1.59	4.5	6.06	
JAV2C1S	4/22/2010		9		5.3	1.70	3.8	6.13	
JAV2C1S	5/18/2010		9.39		6.22	1.51	5.17	3.83	

Block 2, Transect C, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-c1d	1/12/2005	0.005	0.15	5	0.3	0.78						
Jav2-c1d	1/26/2005	0.1	0.13	0.05	1.2	1.9						
Jav2-c1d	2/9/2005	0.005	0.05	5.2	0.01	0.34						
Jav2-c1d	2/23/2005	0.01	0.05	5.9	0.05	0.43						
Jav2-c1d	3/10/2005	0.02	0.05	5.4	0.2	0.26	1.3	2.5	2.16			
Jav2-c1d	3/23/2005	0.005	0.05	1.7	0.04	0.05						
Jav2-c1d	4/6/2005	0.005	0.05	0.05	0.08	0.21	0.5	2.8	0.02			
Jav2-c1d	4/20/2005	0.005	0.05	5.6	0.07	0.41	1.3	4.2	1.33			
Jav2-c1d	5/5/2005	0.005	0.11	5.5	0.14	0.98	1.3	8.7	0.63			
Jav2-c1d	5/18/2005	0.005	0.05	5.9	0.1	0.59	1.3	4.9	1.20			
Jav2-c1d	6/2/2005	0.005	0.05	5.8	0.05	0.46	1.5	4.8	1.21			
Jav2-c1d	6/15/2005	0.005	0.05	5.7	0.005	0.54	1.2	3.7	1.54			
Jav2-c1d	6/29/2005	0.005	0.05	6.2	0.03	0.56	1.3	4.1	1.51			
Jav2-c1d	7/13/2005	0.005	0.11	6.8	0.02	0.32	1.1	4.5	1.51			
Jav2-c1d	7/27/2005	0.005	0.05	6.6			1.8	7.5	0.88			
Jav2-c1d	8/10/2005	0.005	0.05	6.9			1.3	6.2	1.11			
Jav2-c1d	8/23/2005	0.005	0.05	7.2			1.3	6.5	1.11			
Jav2-c1d	9/29/2005	0.005	0.05	8.1			1.1	6.7	1.21			
Jav2-c1d	10/27/2005	0.005	0.16	7.5			1.1	6.5	1.15			
Jav2-c1d	12/1/2005	0.005	0.05	6.2			1.4	3.6	1.72			
Jav2-c1d	1/12/2006	0.005	0.05	13.7			2	23.7	0.58			
Jav2-c1d	2/9/2006	0.005	0.05	14.7			3	24	0.61			
Jav2-c1d	3/9/2006	0.005	0.05	11.9			2.4	18.6	0.64			
Jav2-c1d	4/13/2006	0.005	0.13	10			1.5	12	0.83			
Jav2-c1d	5/12/2006	0.33	0.9	12.7			2.3	18.5	0.69			
Jav2-c1d	6/8/2006	0.005	0.05	11.5			1.6	19.7	0.58			
Jav2-c1d	8/10/2006	0.06	0.48	10.1			2.3	16.9	0.60			
JAV2-C1D	9/20/2006	0.01	0.05	8.3			2.3	13.4	0.62			
JAV2-C1D	10/18/2006	0.005	0.05	7.1			2.6	13.2	0.54			
JAV2-C1D	11/21/2006	0.005	0.05	8.5			2.3	9.9	0.86			
JAV2-C1D	12/20/2006	0.005	0.05	13.1			2	12.4	1.06			

JAV2-C1D	1/24/2007	0.005	0.05	16.7	2	9.5	1.76		
JAV2-C1D	2/21/2007	0.005	0.05	13.5	1.9	9	1.50		
JAV2-C1D	3/21/2007	0.005	0.05	12	1.6	8.9	1.35		
JAV2-C1D	4/1/2007	0.005	0.05	12.6	1.5	10	1.26		
JAV2-C1D-DUP.	4/1/2007	0.03	0.05	10.5	2.2	6.7	1.57		
JAV2-C1D	5/1/2007	0.01	0.05	12.7	1.6	10.2	1.25		
JAV2-C1D	6/1/2007	0.01	0.05	12.6	1.8	10.3	1.22		
JAV2-C1D	7/1/2007	0.01	0.05	12.4	1.4	11.7	1.06		
JAV2-C1D	8/20/2007	0.005	0.05	12.1	1.3	11.6	1.04		
JAV2-C1D	9/17/2007	0.005	0.05	12.8	1.6	11.3	1.13		
JAV2-C1D	10/24/2007	0.005	0.05	10.8	2.5	9.8	1.10		
JAV2-C1D	11/24/2007	0.005	0.05	17.6	2.5	8.4	2.10		
JAV2-C1D	4/22/2008	0.03	0.01	10.57	5.6	22.62	0.47		
JAV2-C1D	5/13/2008	0.05	0.03	17.02	5.26	7.37	2.31		
JAV2-C1D	6/10/2008	0.03	0.06	10.09	10.91	8.37	1.21		
JAV2-C1D	7/8/2008		0.038	11.5		5.59	2.06		
JAV2C1D	8/6/2008		0.22	11.48		7.12	1.61		19.9
JAV2-C1D	9/24/2008		0.013	11.77		8.06	1.46		
JAV2-C1D	10/22/2008		0.00	13		9.03	1.44		0.49
JAV2-C1D	11/19/2008		0.027	11.48		5.49	2.09		3.39
JAV2-C1D	12/17/2008		0	13.37		6.23	2.15		
JAV2-C1D	1/23/2009		0.03	15.06		25.16	0.60		
JAV2C1D	2/17/2009		0.019	14.29		8.68	1.65		1.42
JAV2C1D	3/24/2009			17.54		7.93	2.21	8.76	18.3
JAV2C1D	4/21/2009			14.47		7.42	1.95	8.29	19.7
JAV2C1D	5/28/2009			15.48		8.06	1.92	11.9	14.6
JAV2C1D	6/29/2009		0.03	14.35		7.22	1.99	8.6	13.8
JAV2C1D	7/21/2009			14.89		8.17	1.82	8.8	20.4
JAV2C1D	8/18/2009			14.39		7.88	1.83	8	1.2
JAV2C1D	9/15/2009			13.65		7.37	1.85	10.9	3.3
JAV2C1D	10/20/2009		0.03	13.36		8.11	1.65	9.6	6.02
JAV2C1D	11/17/2009			14.35		5.39	2.66	9.7	14.5
JAV2C1D	12/15/2009			13.28		7.79	1.70	7.29	9
JAV2C1D	1/19/2010			11.49		6.77	1.70	6.16	13.5
JAV2C1D	2/18/2010		0.03	10.18		5.93	1.72	5.78	13.8
JAV2C1D	3/16/2010			9.8		5.92	1.66	5.8	6.46
JAV2C1D	4/22/2010			9.42		5.46	1.73	5.17	7.81
JAV2C1D	5/18/2010			9.74		6.92	1.41	5.52	4.41

Block 2, Transect C, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-c2s	1/12/2005	0.03	0.51	0.05	0.61	0.44						
Jav2-c2s	1/26/2005	0.12	0.05	1.1	1.4	0.72						
Jav2-c2s	2/9/2005	0.08	0.28	0.05	0.99	2						
Jav2-c2s	2/23/2005	0.12	0.23	0.11	2.1	4.9						
Jav2-c2s	3/10/2005	0.07	0.16	0.18	0.51	1.2	6.7	1.4	0.13			
Jav2-c2s	3/23/2005	0.005	0.05	0.92	0.21	0.38						
Jav2-c2s	4/20/2005	0.005	0.05	1	0.4	0.84	4.6	11.2	0.09			
Jav2-c2s	5/5/2005	0.005	0.05	1	0.3	0.69	3.3	10.4	0.10			
Jav2-c2s	4/6/2005	0.005	0.05	0.26	0.35	0.99	4.5	6.5	0.04			
Jav2-c2s	5/18/2005	0.005	0.05	1.4	0.44	0.8	3.3	6.1	0.23			
Jav2-c2s	6/2/2005	0.005	0.05	1	1.1	2	3.3	5.7	0.18			
Jav2-c2s	8/10/2005	0.02	0.05	2.4			0.5	4.5	0.53			
Jav2-c2s	1/12/2006	0.005	0.05	0.76			3	5.6	0.14			
Jav2-c2s	2/9/2006	0.005	0.05	1			4.3	5.4	0.19			
Jav2-c2s	3/9/2006	0.04	0.05	1.6			3.8	11.3	0.14			
Jav2-c2s	5/12/2006	0.03	0.05	2.4			1.8	4.2	0.57			
Jav2-c2s	8/10/2006	0.83	0.63	0.49			10.5	5.3	0.09			
JAV2-C2S	10/18/2006	0.33	0.05	1.7			6.6	4	0.43			
JAV2-C2S	11/21/2006	0.12	0.05	0.5			7.4	4.5	0.11			
JAV2-C2S	12/20/2006	0.2	0.05	0.24			9.9	2.9	0.08			
JAV2-C2S	1/24/2007	0.07	0.05	0.38			7	4.1	0.09			
JAV2-C2S	2/21/2007	0.12	0.05	0.45			8.3	3	0.15			
JAV2-C2S	3/21/2007	0.1	0.05	0.66			7.9	2.6	0.25			
JAV2-C2S	4/22/2008	0.08	0.03	1.3			7.51	9.08	0.14			
JAV2C2S	3/24/2009			4.21				15.07	0.28			
JAV2C2S	11/17/2009			4.31				8.99	0.48			
JAV2C2S	12/15/2009			1.34				8.47	0.16			
JAV2C2S	1/19/2010			0.43				5.19	0.08			
JAV2C2S	2/18/2010		0.03	0.72				2.21	0.33			14.26
JAV2C2S	3/16/2010			0.76				2.33	0.33			
JAV2C2S	5/18/2010			1.09				4.8	0.23			

Block 2, Transect C, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-c2d	1/12/2005	0.08	0.05	1.2	0.43	2.3						
Jav2-c2d	1/26/2005	0.04	0.05	3.6	0.24	0.14						
Jav2-c2d	2/9/2005	0.08	0.05	0.99	0.55	0.53						
Jav2-c2d	2/23/2005	0.11	0.05	1.4	0.97	0.9						
Jav2-c2d	3/10/2005	0.06	0.05	1.1	0.6	0.58	4.5	1.1	1.00			
Jav2-c2d	3/23/2005	0.005	0.05	5.5	0.03	0.12						
Jav2-c2d	4/6/2005	0.01	0.05	0.34	0.06	0.72	2.9	2	0.17			
Jav2-c2d	4/20/2005	0.005	0.05	1.5	0.05	0.32	2	3.1	0.48			
Jav2-c2d	5/5/2005	0.005	0.05	2.9	0.07	0.2	1.3	4.3	0.67			
Jav2-c2d	5/18/2005	0.005	0.34	4.6	0.27	1.5	1.3	5.6	0.82			
Jav2-c2d	6/2/2005	0.03	0.05	3.3	0.25	0.61	1.9	4.4	0.75			
Jav2-c2d	6/15/2005	0.005	0.05	4.5	0.07	0.87	1.3	4.4	1.02			
Jav2-c2d	6/29/2005	0.005	0.05	6	0.1	0.48	1.2	4.3	1.40			
Jav2-c2d	7/13/2005	0.005	0.05	6.4	0.04	0.23	0.5	4	1.60			
Jav2-c2d	7/27/2005	0.005	0.05	6.4			1.5	7	0.91			
Jav2-c2d	8/10/2005	0.005	0.05	6			1.1	5.7	1.05			
Jav2-c2d	8/23/2005	0.005	0.05	6.2			0.5	5.7	1.09			
Jav2-c2d	9/29/2005	0.01	0.05	6.2			1.6	5.6	1.11			
Jav2-c2d	10/27/2005	0.005	0.05	5.8			0.5	5.7	1.02			
Jav2-c2d	12/1/2005	0.005	0.05	5.7			1.3	3.7	1.54			
Jav2-c2d	1/12/2006	0.005	0.05	3.1			2.2	5	0.62			
Jav2-c2d	2/9/2006	0.005	0.05	3.3			3.3	4.4	0.75			
Jav2-c2d	3/9/2006	0.005	0.05	4			2.5	4.3	0.93			
Jav2-c2d	4/13/2006	0.005	0.11	4.4			0.5	3.7	1.19			
Jav2-c2d	5/12/2006	0.005	0.05	4.2			1.2	3.2	1.31			
Jav2-c2d	6/8/2006	0.005	0.05	4.8			2.7	3.6	1.33			
Jav2-c2d	8/10/2006	0.04	0.26	4.1			2	6.6	0.62			
JAV2-C2D	9/20/2006	0.04	0.19	4.3			1.5	2.5	1.72			
JAV2-C2D	10/18/2006	0.03	0.05	4.9			1.8	2.7	1.81			
JAV2-C2D	11/21/2006	0.02	0.05	1.9			3.4	2.7	0.70			
JAV2-C2D	12/20/2006	0.03	0.05	2.7			1.9	2.1	1.29			
JAV2-C2D	1/24/2007	0.01	0.05	1.7			2.3	3.6	0.47			
JAV2-C2D	2/21/2007	0.03	0.05	3.3			1.4	3.9	0.85			
JAV2-C2D	3/21/2007	0.02	0.05	3.3			1.3	4.4	0.75			
JAV2-C2D	4/1/2007	0.01	0.05	5.2			0.5	4.1	1.27			
JAV2-C2D	5/1/2007	0.04	0.05	5.1			1.2	3.4	1.50			
JAV2-C2D	6/1/2007	0.06	0.05	5.2			1.4	3.9	1.33			
JAV2-C2D	7/1/2007	0.06	0.05	5.5			1.6	4.8	1.15			
JAV2-C2D	8/20/2007	0.08	0.05	5.6			1.4	5.3	1.06			
JAV2-C2D	9/17/2007	0.03	0.05	6.1			1.1	5.4	1.13			
JAV2-C2D	10/24/2007	0.05	0.05	5			2.4	4.5	1.11			

JAV2-C2D	11/24/2007	0.03	0.05	5.2		1.8	3.1	1.68				
JAV2-C2D	4/22/2008	0.06	0.01	4.47		4.51	8.87	0.50				
JAV2-C2D	5/13/2008	0.05	0.04	6.03		4.66	5.61	1.07				
JAV2-C2D	6/10/2008	0.05	0.01	3.07		5.25	5.86	0.52				
JAV2-C2D	7/8/2008		0.042	3.49			3.73	0.94				
JAV2C2D	8/6/2008		0.04	4.06			6.67	0.61				17.61
JAV2-C2D	9/24/2008		0.014	4.34			7.93	0.55				
JAV2-C2D	10/22/2008		0.02	4.78			8.25	0.58				0.00
JAV2-C2D	11/19/2008		0.013	4.23			5.85	0.72				1.7
JAV2-C2D	12/17/2008		0	5.21			7.29	0.71				
JAV2-C2D	1/23/2009		0.03	5.86			19.07	0.31				
JAV2C2D	2/17/2009		0.013	5.76			6.43	0.90				0.96
JAV2C2D	3/24/2009			2.06			4.37	0.47				
JAV2C2D	4/21/2009			4.83			5.52	0.88				1.81
JAV2C2D	5/28/2009			3.17			5.25	0.60	2.9	2.9		
JAV2C2D	6/29/2009		0.04	3.46			6.01	0.58	3.1	1.3		0.8
JAV2C2D	7/21/2009			2.72			6.05	0.45				
JAV2C2D	8/18/2009			3.3			6.57	0.50	4.1	0.3		0.95
JAV2C2D	9/15/2009			4.4			7.63	0.58				
JAV2C2D	10/20/2009		0.03	4.4			7.34	0.60				5.26
JAV2C2D	11/17/2009			1.81			16.74	0.11				
JAV2C2D	12/15/2009			1.35			5.61	0.24				5.18
JAV2C2D	1/19/2010			1.35			4.66	0.29				
JAV2C2D	2/18/2010		0.03	0.76			2.64	0.29				
JAV2C2D	3/16/2010			1.69			4.08	0.41				
JAV2C2D	4/22/2010			1.84			4.09	0.45				
JAV2C2D	5/18/2010			2.04			4.84	0.42				

Block 2, Transect C, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-c3s	1/12/2005	0.06	0.05	3.2	0.16	0.83						
Jav2-c3s	1/26/2005	0.01	0.05	4.7	0.1	1.3						
Jav2-c3s	2/9/2005	0.02	0.05	3.8	0.09	0.28						
Jav2-c3s	2/23/2005	0.04	0.05	3.7	0.12	0.39						
Jav2-c3s	3/10/2005	0.03	0.05	4.6	0.12	0.2	0.5	3.4	1.35			
Jav2-c3s	3/23/2005	0.005	0.05	2.8	0.01	0.05						
Jav2-c3s	4/6/2005	0.005	0.05	5.1	0.04	0.26	4.3	3.7	1.38			
Jav2-c3s	4/20/2005	0.005	0.05	3.4	0.06	0.27	0.5	5	0.68			
Jav2-c3s	5/5/2005	0.005	0.05	2.7	0.05	0.17	1.3	3.7	0.73			
Jav2-c3s	5/18/2005	0.005	0.05	3	0.03	0.59	0.5	4.4	0.68			
Jav2-c3s	6/2/2005	0.04	0.05	3.2	0.07	0.7	3.7	4.5	0.71			
Jav2-c3s	6/15/2005	0.005	0.05	2.6	0.02	0.41	0.5	3.1	0.84			
Jav2-c3s	6/29/2005	0.005	0.05	2.5	0.09	0.2	0.5	3	0.83			

Jav2-c3s	7/13/2005	0.005	0.05	2.4	0.08	0.34	0.5	2.9	0.83										
Jav2-c3s	7/27/2005	0.005	0.05	2.5			0.5	5.7	0.44										
Jav2-c3s	9/29/2005	0.06	0.05	2			2.4	4.6	0.43										
Jav2-c3s	10/27/2005	0.03	0.05	2.4			0.5	4.3	0.56										
Jav2-c3s	12/1/2005	0.01	0.05	2.7			0.5	3.1	0.87										
Jav2-c3s	1/12/2006	0.005	0.14	3			0.5	3.7	0.81										
Jav2-c3s	2/9/2006	0.005	0.05	3.2			1.6	3.7	0.86										
Jav2-c3s	3/9/2006	0.02	0.05	2.8			1.4	4.3	0.65										
Jav2-c3s	4/13/2006	0.005	0.05	2.8			3	3	0.93										
Jav2-c3s	5/12/2006	0.02	0.05	2.7			0.5	2.8	0.96										
Jav2-c3s	6/8/2006	0.005	0.21	2.2			1.3	3.1	0.71										
Jav2-c3s	8/10/2006	0.04	0.05	2.3			0.5	2.9	0.79										
JAV2-C3S	9/20/2006	0.05	0.05	1.8			1	1.8	1.00										
JAV2-C3S	10/18/2006	0.05	0.05	2			1.4	1.7	1.18										
JAV2-C3S	11/21/2006	0.04	0.05	2.5			0.5	1.9	1.32										
JAV2-C3S	12/20/2006	0.05	0.05	2.3			0.5	1.3	1.77										
JAV2-C3S	1/24/2007	0.03	0.05	2.4			0.5	2.9	0.83										
JAV2-C3S	2/21/2007	0.04	0.05	2.3			0.5	2	1.15										
JAV2-C3S	3/21/2007	0.03	0.05	2.2			1.2	2.2	1.00										
JAV2-C3S	4/1/2007	0.03	0.05	2.3			0.5	2.5	0.92										
JAV2-C3S	5/1/2007	0.04	0.05	1.9			0.5	1.5	1.27										
JAV2-C3S	6/1/2007	0.04	0.05	2.2			0.5	1.5	1.47										
JAV2-C3S	7/1/2007	0.06	0.05	2.2			0.5	1.8	1.22										
JAV2-C3S	8/20/2007	0.06	0.05	2.3			0.5	1.8	1.28										
JAV2-C3S	9/17/2007	0.03	0.05	2.2			0.5	1.9	1.16										
JAV2-C3S	10/24/2007	0.17	0.14	1.2			2.7	2.3	0.52										
JAV2-C3S	4/22/2008	0.11	0.01	1.73			3.7	4.61	0.38										
JAV2-C3S	5/13/2008	0.13	0.04	1.02			3.98	4.46	0.23										
JAV2-C3S	6/10/2008	0.1	0.10	0.33			4.94	5.28	0.06										
JAV2-C3S	7/8/2008		0.017	0.73				2.09	0.35	4.77	4.6								
JAV2C3S	8/6/2008		0.08	0.59				3.47	0.17									18.41	
JAV2-C3S	9/24/2008		0.037	1.02				4.42	0.23										
JAV2-C3S	12/17/2008		0	1.31				4.33	0.30										
JAV2-C3S	1/23/2009		0.03	2.12				12	0.18										
JAV2C3S	2/17/2009		0.013	2.12				3.61	0.59	4.6	5.1	0.4							
JAV2C3S	3/24/2009			2.02				3.98	0.51	4.49	6								
JAV2C3S	4/21/2009			1.58				4.17	0.38	4.95	6.2	0.53							
JAV2C3S	5/28/2009			0.36						4.6	3.4								
JAV2C3S	6/29/2009		0.08	0.57				4.14	0.14	5.1	2.2	1.55							
JAV2C3S	8/18/2009			0.7				4.01	0.17										
JAV2C3S	9/15/2009			1.11				4.48	0.25	4.93	1.2								
JAV2C3S	11/17/2009			4.76				3.34	1.43	4.2	7.8								
JAV2C3S	12/15/2009			2.31				4.94	0.47	4.82	1.54	1.71							
JAV2C3S	1/19/2010			1.79				4.08	0.44	4.34	5.9								
JAV2C3S	2/18/2010		0.04	1.92				4.28	0.45	4.72	6	1.87							

JAV2C3S	3/16/2010		1.6		4.47	0.36	1.5	2.52
JAV2C3S	4/22/2010		1.99		4.79	0.42	4.68	0.95
JAV2C3S	5/18/2010		1.8		4.83	0.37	4.92	0.51

Block 2, Transect C, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav2-c3d	1/12/2005	0.03	0.05	1.9	0.11	0.78						
Jav2-c3d	1/26/2005	0.01	0.05	1.9	0.03	1.2						
Jav2-c3d	2/9/2005	0.01	0.2	2.2	0.03	0.25						
Jav2-c3d	2/9/2005	0.02	0.05	3.9	0.06	0.27						
Jav2-c3d	2/23/2005	0.03	0.05	2.2	0.09	0.45						
Jav2-c3d	3/10/2005	0.005	0.05	2.5	0.03	0.47	0.5	2.2	1.14			
Jav2-c3d	3/23/2005	0.08	0.05	1	0.1	0.1						
Jav2-c3d	4/20/2005	0.005	0.12	2.4	0.04	0.53	0.5	3.8	0.63			
Jav2-c3d	5/5/2005	0.01	0.05	2.3	0.07	0.48	0.5	8.1	0.28			
Jav2-c3d	4/6/2005	0.005	0.05	2.4	0.06	0.6	0.5	4.1	0.59			
Jav2-c3d	5/18/2005	0.005	0.05	2.2	0.05	0.68	2.1	4	0.55			
Jav2-c3d	6/2/2005	0.005	0.05	2.6	0.04	0.59	1.6	4	0.65			
Jav2-c3d	6/15/2005	0.005	0.05	2.3	0.02	0.47	0.5	2.8	0.82			
Jav2-c3d	6/29/2005	0.05	0.05	2.5	0.11	0.32	0.5	2.8	0.89			
Jav2-c3d	7/13/2005	0.02	0.05	2.6	0.005	0.21	0.5	2.7	0.96			
Jav2-c3d	7/27/2005	0.005	0.05	2.4			1.7	5.9	0.41			
Jav2-c3d	8/10/2005	0.01	0.05	2.2			1.5	4.3	0.51			
Jav2-c3d	8/23/2005	0.01	0.05	0.7			1.5	3.4	0.21			
Jav2-c3d	9/29/2005	0.01	0.05	2.3			0.5	4.1	0.56			
Jav2-c3d	10/27/2005	0.01	0.05	2.4			0.5	4.2	0.57			
Jav2-c3d	12/1/2005	0.005	0.05	2.3			1.3	2.6	0.88			
Jav2-c3d	1/12/2006	0.005	0.05	2.3			0.5	2.8	0.82			
Jav2-c3d	2/9/2006	0.005	0.05	2.3			1.6	2.7	0.85			
Jav2-c3d	3/9/2006	0.005	0.05	1.8			1.1	3.9	0.46			
Jav2-c3d	4/13/2006	0.01	0.05	1.6			0.5	4	0.40			
Jav2-c3d	5/12/2006	0.005	0.05	1.6			0.5	2	0.80			
Jav2-c3d	6/8/2006	0.01	0.14	1.6			1.6	2.4	0.67			
Jav2-c3d	8/10/2006	0.02	0.05	2			0.5	3.5	0.57			
JAV2-C3D	9/20/2006	0.03	0.05	1.6			0.5	1.7	0.94			
JAV2-C3D	10/18/2006	0.01	0.05	2			1.6	1.5	1.33			
JAV2-C3D	11/21/2006	0.02	0.05	2.2			0.5	1.4	1.57			
JAV2-C3D	12/20/2006	0.02	0.05	2.4			1	1	2.40			
JAV2-C3D	1/24/2007	0.01	0.05	2.3			1.1	2.4	0.96			
JAV2-C3D	2/21/2007	0.01	0.05	2.3			0.5	1.4	1.64			
JAV2-C3D	3/21/2007	0.02	0.05	2.3			0.5	1.5	1.53			
JAV2-C3D	4/1/2007	0.01	0.05	2.3			0.5	2	1.15			

JAV2-C3D	5/1/2007	0.02	0.05	2.4		1.3	1.3	1.85				
JAV2-C3D	6/1/2007	0.02	0.05	2.3		0.5	1.4	1.64				
JAV2-C3D	7/1/2007	0.02	0.05	2.3		0.5	1.6	1.44				
JAV2-C3D	8/20/2007	0.01	0.05	2.6		0.5	2.5	1.04				
JAV2-C3D	9/17/2007	0.01	0.05	2.7		0.5	2.1	1.29				
JAV2-C3D	10/24/2007	0.02	0.18	2.5		2.2	2.4	1.04				
JAV2-C3D	11/24/2007	0.01	0.05	2.6		1.4	1.1	2.36				
JAV2-C3D	4/22/2008	0.1	0.08	1.42		4.21	3.02	0.47				
JAV2-C3D	5/13/2008	0.1	0.06	1.72		6.56	3.3	0.52				
JAV2-C3D	6/10/2008	0.07	0.00	1.3		4.01	3.87	0.34				
JAV2-C3D	7/8/2008		0.061	1.67			2.15	0.78	4.8	2.5		
JAV2C3D	8/6/2008		0.04	1.79			3.94	0.45				17.91
JAV2-C3D	9/24/2008		0.017	2.03			4.44	0.46				
JAV2-C3D	10/22/2008		0.00	2.23			4.53	0.49				0.51
JAV2-C3D	11/19/2008		0.011	2.28			2.78	0.82	4.94	4		0.96
JAV2-C3D	12/17/2008		0	2.35			4.24	0.55				
JAV2-C3D	1/23/2009		0.03	2.37			11.19	0.21				
JAV2C3D	2/17/2009		0.005	2.39			3.53	0.68	5.2	3.5		0.18
JAV2C3D	3/24/2009			2.32			3.18	0.73	5.19	2.9		
JAV2C3D	4/21/2009			2.05			3.88	0.53	5.01	3.4		2.54
JAV2C3D	5/28/2009			2.23			2.9	0.77	4.7	1.1		
JAV2C3D	6/29/2009		0.04	2.29			4.27	0.54	2.3	6.8		1.06
JAV2C3D	7/21/2009			2.27			3.34	0.68	5.4	4.9		
JAV2C3D	8/18/2009			2.29			3.84	0.60	4.5	0.17		0.69
JAV2C3D	9/15/2009			2.3			4.05	0.57	4.54	0.7		
JAV2C3D	10/20/2009		0.04	2.43			3.77	0.64	4.8	0.05		3.99
JAV2C3D	11/17/2009			2.46			3.25	0.76	4.9	3.5		
JAV2C3D	12/15/2009			2.46			4.43	0.56	4.99	0.49		1.29
JAV2C3D	1/19/2010			2.12			3.79	0.56	4.28	3.5		
JAV2C3D	2/18/2010		0.01	1.98			3.69	0.54	4.6	3.2		1.31
JAV2C3D	3/16/2010			1.86			3.74	0.50	4.4	1.36		
JAV2C3D	4/22/2010			2			3.16	0.63	4.43	0.39		
JAV2C3D	5/18/2010			1.88			4.13	0.46	4.49	0		

Block 3, Transect A, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-a1s	1/12/2005	0.02	0.05	0.59	0.06	0.37						
Jav3-a1s	1/26/2005	0.005	0.05	0.76	0.1	0.58						
Jav3-a1s	2/9/2005	0.005	0.05	1.20	0.005	0.58						
Jav3-a1s	2/23/2005	0.005	0.05	1.50	0.04	0.35						
Jav3-a1s	3/10/2005	0.005	0.05	2.70	0.005	0.53	0.5	1.6	1.69			

Jav3-a1s	3/23/2005	0.005	0.05	2.50	0.04	0.2													
Jav3-a1s	4/6/2005	0.005	0.05	7.80	0.04	0.38	0.5	2.3	3.39										
Jav3-a1s	4/20/2005	0.005	0.05	6.10	0.06	0.59	1.3	3.5	1.74										
Jav3-a1s	5/5/2005	0.005	0.05	5.60	0.04	0.3	0.5	7.8	0.72										
Jav3-a1s	5/18/2005	0.005	0.05	5.40	0.07	0.41	1.3	3.8	1.42										
Jav3-a1s	6/2/2005	0.005	0.05	5.10	0.09	0.35	1.5	2.7	1.89										
Jav3-a1s	6/15/2005	0.005	0.05	4.50	0.5	1.9	1.3	2.9	1.55										
Jav3-a1s	6/29/2005	0.005	0.05	0.15	0.02	0.15	1.1	1.5	0.10										
Jav3-a1s	1/12/2006	0.005	0.05	0.26			1.2	1.5	0.17										
Jav3-a1s	2/9/2006	0.005	0.05	0.26			1.9	5	0.05										
Jav3-a1s	3/9/2006	0.005	0.05	0.76			2.6	5.4	0.14										
Jav3-a1s	8/10/2006	0.18	0.16	1.50			5.6	29.2	0.05										
JAV3-A1S	11/21/2006	0.02	0.05	1.60			2.7	10	0.16										
JAV3-A1S	12/20/2006	0.03	0.05	2.40			3	7.6	0.32										
JAV3-A1S	1/24/2007	0.02	0.05	4.20			2.6	12.3	0.34										
JAV3-A1S	2/21/2007	0.03	0.05	3.50			2.9	10.1	0.35										
JAV3-A1S	3/21/2007	0.04	0.05	2.40			3.8	7.3	0.33										
JAV3-A1S	4/1/2007	0.06	0.05	1.90			4.5	8.3	0.23										
JAV3-A1S	4/22/2008	0.03	0.03	8.07			4.92	6.35	1.27										
JAV3-A1S	5/13/2008	0.03	0.05	4.67			5.17	4.68	1.00										
JAV3-A1S	6/10/2008	0.04	0.04	3.39				9.42	0.36										
JAV3A1S	3/24/2009			3.46				3.82	0.91	4.6	26.7								
JAV3A1S	4/21/2009			4.42				5.47	0.81	4.12	29	1.82							
JAV3A1S	11/17/2009			6.84				1.99	3.44	5.1	21.5								
JAV3A1S	12/15/2009			3.49				4.1	0.85			4.29							
JAV3A1S	1/19/2010			2.01				3.62	0.56	2.99	16.9								
JAV3A1S	2/18/2010		0.02	2.02				3.41	0.59	3.36	15.2	2.74							
JAV3A1S	3/16/2010			1.26				3.62	0.35	3.6	7.39								
JAV3A1S	4/22/2010			0.91				4.54	0.20	3.89	8.29								

Block 3 Transect A, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-a1d	1/12/2005	0.02	0.05	2	0.09	1.2						
Jav3-a1d	1/26/2005	0.005	0.05	0.92	0.07	0.86						
Jav3-a1d	2/9/2005	0.005	0.05	2.3	0.005	0.18						
Jav3-a1d	2/23/2005	0.01	0.05	1.9	0.09	0.6						
Jav3-a1d	3/10/2005	0.005	0.05	2.2	0.005	0.35	1.1	2	1.10			
Jav3-a1d	3/23/2005	0.005	0.05	4.4	0.05	0.26						
Jav3-a1d	4/6/2005	0.01	0.05	2.4	0.05	0.48	1.2	2.3	1.04			
Jav3-a1d	4/20/2005	0.005	0.05	4.1	0.08	0.67	1	3.5	1.17			
Jav3-a1d	5/5/2005	0.005	0.05	4.4	0.08	0.39	1.2	7	0.63			
Jav3-a1d	5/18/2005	0.005	0.05	4.9	0.09	0.68	1.1	4	1.23			
Jav3-a1d	6/2/2005	0.005	0.05	4.3	0.07	0.5	1.2	3	1.43			

Jav3-a1d	6/15/2005	0.005	0.05	4.6	0.01	0.41	1.1	2.8	1.64											
Jav3-a1d	6/29/2005	0.005	0.05	4.5	0.005	0.24	0.5	3	1.50											
Jav3-a1d	7/13/2005	0.005	0.14	4.6	0.005	0.37	0.5	3.2	1.44											
Jav3-a1d	7/27/2005	0.005	0.05	4.6			1.7	6.5	0.71											
Jav3-a1d	8/10/2005	0.005	0.05	5			0.5	5.6	0.89											
Jav3-a1d	8/23/2005	0.005	0.05	6.1			1.2	6.9	0.88											
Jav3-a1d	9/29/2005	0.12	4.9	6.3			3.5	9.7	0.65											
Jav3-a1d	10/27/2005	0.005	0.05	7.9			0.5	9	0.88											
Jav3-a1d	12/1/2005	0.005	0.05	7.2			1.4	6.1	1.18											
Jav3-a1d	1/12/2006	0.005	0.05	2.5			1.8	3.1	0.81											
Jav3-a1d	2/9/2006	0.005	0.05	1.8			1.9	2.9	0.62											
Jav3-a1d	3/9/2006	0.005	0.14	1.6			1.8	5.2	0.31											
Jav3-a1d	4/13/2006	0.02	0.92	1.4			2.1	3.8	0.37											
Jav3-a1d	5/12/2006	0.005	0.05	1.1			1	4.2	0.26											
Jav3-a1d	6/8/2006	0.005	0.05	0.77			1.8	10.7	0.07											
Jav3-a1d	8/10/2006	0.02	0.05	3.3			2	35.9	0.09											
JAV3-A1D	9/20/2006	0.03	0.05	2.8			1.6	29.3	0.10											
JAV3-A1D	10/18/2006	0.01	0.05	2.5			2.4	28.7	0.09											
JAV3-A1D	11/21/2006	0.005	0.05	2			1.4	27.8	0.07											
JAV3-A1D	12/20/2006	0.005	0.05	1.5			1.4	21.6	0.07											
JAV3-A1D	1/24/2007	0.005	0.05	2.1			1.5	17.7	0.12											
JAV3-A1D	2/21/2007	0.005	0.05	2.3			1.7	13.6	0.17											
JAV3-A1D	3/21/2007	0.005	0.05	1.9			1.7	13.3	0.14											
JAV3-A1D	4/1/2007	0.005	0.05	2			1.6	11.7	0.17											
JAV3-A1D	5/1/2007	0.04	0.05	2			1.6	10	0.20											
JAV3-A1D	6/1/2007	0.02	0.05	2.3			1.7	9.3	0.25											
JAV3-A1D	7/1/2007	0.04	0.05	2.4			1.6	10.8	0.22											
JAV3-A1D	8/20/2007	0.04	0.05	3.2			1.7	10.7	0.30											
JAV3-A1D	11/24/2007	0.04	0.05	2.9			2.5	9.2	0.32											
JAV3-A1D	4/22/2008	0.04	0.01	9.4			4.4	7.36	1.28											
JAV3-A1D	5/13/2008	0.06	0.09	9.99			4.27	7.33	1.36											
JAV3-A1D	6/10/2008	0.03	0.04	8.08			5.54	8.67	0.93											
JAV3A1D	8/6/2008		0.13	7.05				10.73	0.66										18.97	
JAV3-A1D	9/24/2008		0.028	5.81				12.21	0.48											
JAV3-A1D	10/22/2008		0.01	5.97				11.54	0.52											
JAV3-A1D	11/19/2008		0.014	6.49				9.3	0.70										3.32	
JAV3-A1D	12/17/2008		0	5.4				8.98	0.60											
JAV3-A1D	1/23/2009		0.03	3.53				27.73	0.13											
JAV3A1D	2/17/2009		0.011	2.78				6.97	0.40										0.9	
JAV3A1D	3/24/2009			3.07				5.09	0.60	4.82	25.8									
JAV3A1D	4/21/2009			4.2				6.01	0.70	4.74	27.5	1.49								
JAV3A1D	5/28/2009			5.16				5.23	0.99	4.5	20.2									
JAV3A1D	6/29/2009		0.05	5.4				6.3	0.86	5	18.7	1.74								
JAV3A1D	7/21/2009			5.62				7.41	0.76	5.9	28.9									
JAV3A1D	8/18/2009			5.51				7.58	0.73	5.2	1.84	2.19								

JAV3A1D	9/15/2009		5.78		8.84	0.65	4.96	4.4	
JAV3A1D	11/17/2009		5.51		6.63	0.83	4.2	24.4	
JAV3A1D	12/15/2009		4.51		7.47	0.60	3.98	15.3	2.88
JAV3A1D	1/19/2010		4.43		6.02	0.74	3.68	22	
JAV3A1D	2/18/2010	0.03	3.17		4.84	0.65	3.83	19.9	2.7
JAV3A1D	3/16/2010		2.41		4.65	0.52	3.9	9.35	
JAV3A1D	4/22/2010		1.73		3.85	0.45	3.6	10.84	
JAV3A1D	5/18/2010		3.59		6.69	0.54	3.88	6.21	

Block 3, Transect A, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-a2s	1/12/2005	0.02	0.83	0.05	0.09	0.41						
Jav3-a2s	1/26/2005	0.01	0.05	0.44	0.08	1.3						
Jav3-a2s	2/9/2005	0.005	0.05	0.65	0.06	0.05						
Jav3-a2s	2/23/2005	0.03	0.05	0.05	0.03	0.4						
Jav3-a2s	3/10/2005	0.005	0.05	1	0.005	0.36	1.5	1.2	0.83			
Jav3-a2s	3/23/2005	0.005	0.05	2.5	0.02	0.2						
Jav3-a2s	4/6/2005	0.005	0.05	0.34	0.05	0.17	2.2	2	0.17			
Jav3-a2s	4/20/2005	0.005	0.05	0.2	0.04	0.35	2	2.4	0.08			
Jav3-a2s	5/5/2005	0.005	0.05	0.2	0.02	0.18	1.6	3.1	0.06			
Jav3-a2s	5/18/2005	0.005	0.05	0.16	0.1	0.5	2.4	2.7	0.06			
Jav3-a2s	6/2/2005	0.005	0.05	0.22	0.11	0.55	1.7	2	0.11			
Jav3-a2s	6/15/2005	0.005	0.05	0.17	0.02	0.45	1.3	1.7	0.10			
Jav3-a2s	6/29/2005	0.005	0.05	0.13	0.05	0.62	2.4	1.8	0.07			
Jav3-a2s	7/13/2005	0.005	0.05	0.29	0.09	0.59	1.2	1.9	0.15			
Jav3-a2s	7/27/2005	0.005	0.05	0.16			2	4.5	0.04			
Jav3-a2s	8/10/2005	0.005	0.05	0.44			1.8	3.2	0.14			
Jav3-a2s	1/12/2006	0.005	0.05	1.6			2.2	3.7	0.43			
Jav3-a2s	2/9/2006	0.005	0.05	2			2.8	3.9	0.51			
Jav3-a2s	3/9/2006	0.005	0.05	1.8			1.8	5.8	0.31			
Jav3-a2s	4/13/2006	0.01	0.05	1.2			1.9	4.1	0.29			
Jav3-a2s	5/12/2006	0.005	0.05	0.98			1.4	2.1	0.47			
Jav3-a2s	6/8/2006	0.005	0.05	0.44			2	2.8	0.16			
Jav3-a2s	8/10/2006	0.01	0.05	0.89			2.2	7.3	0.12			
JAV3-A2S	9/20/2006	0.03	0.05	0.05			2.7	2.9	0.02			
JAV3-A2S	10/18/2006	0.03	0.05	0.63			3.5	2.7	0.23			
JAV3-A2S	11/21/2006	0.005	0.05	4.3			2.5	2.8	1.54			
JAV3-A2S	12/20/2006	0.02	0.05	1.9			2.7	2.3	0.83			
JAV3-A2S	1/24/2007	0.01	0.05	1.8			2.3	4.4	0.41			
JAV3-A2S	2/21/2007	0.01	0.05	2			2.3	4.8	0.42			
JAV3-A2S	3/21/2007	0.01	0.05	2.3			2.1	5.2	0.44			
JAV3-A2S	4/1/2007	0.07	0.05	1.9			4.2	6.1	0.31			

JAV3-A2S	5/1/2007	0.03	0.05	1.9		2.7	4.8	0.40			
JAV3-A2S	4/22/2008	0.02	0.01	0.84		4.51	5.35	0.16			
JAV3-A2S	5/13/2008	0.02	0.02	0.2		4.68	3.9	0.05			
JAV3-A2S	6/10/2008	0.02	0.06	0.3		5.47	5.97	0.05			
JAV3A2S	8/6/2008		0.07	0.12			6.95	0.02			19.22
JAV3-A2S	12/17/2008		0.13	0.45			9.79	0.05			
JAV2-A2S	1/23/2009		0.16	0			43.39	0.00			
JAV3A2S	2/17/2009		0.051	0			9.45	0.00			1.57
JAV3A2S	3/24/2009			5.99			6.76	0.89			
JAV3A2S	4/21/2009			3.45			6.53	0.53			2.2
JAV3A2S	5/28/2009			0.3			7.07	0.04			
JAV3A2S	6/29/2009		0.06	0.07			8.12	0.01			
JAV3A2S	11/17/2009			1.39			33.36	0.04			
JAV3A2S	12/15/2009			2.95			10.81	0.27			4.58
JAV3A2S	1/19/2010			1.96			5.81	0.34			
JAV3A2S	2/18/2010		0.02	2.95			3.92	0.75			3.14
JAV3A2S	3/16/2010			2.32			3.86	0.60			
JAV3A2S	4/22/2010			1.73			3.46	0.50			
JAV3A2S	5/18/2010			0.8			4.45	0.18			

Block 3, Transect A, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-a2d	1/12/2005	0.01	0.05	1.4	0.09	0.65						
Jav3-a2d	1/26/2005	0.005	0.05	0.63	0.09	0.61						
Jav3-a2d	2/9/2005	0.01	0.05	1.4	0.13	0.27						
Jav3-a2d	2/23/2005	0.02	0.05	1.1	0.18	0.56						
Jav3-a2d	3/10/2005	0.005	0.05	0.79	0.02	0.32	1.8	1.3	0.61			
Jav3-a2d	3/23/2005	0.005	0.05	1.8	0.08	0.14						
Jav3-a2d	4/20/2005	0.005	0.05	0.51	0.04	0.56	1.2	1.6	0.32			
Jav3-a2d	5/5/2005	0.005	0.05	0.47	0.09	0.38	1.5	2.1	0.22			
Jav3-a2d	4/6/2005	0.005	0.05	0.48	0.08	1	1.1	0.5	0.96			
Jav3-a2d	5/18/2005	0.005	0.05	0.75	0.03	0.76	1.8	1.7	0.44			
Jav3-a2d	6/2/2005	0.005	0.22	0.81	0.005	0.54	2	1.3	0.62			
Jav3-a2d	6/15/2005	0.005	0.05	1	0.005	1.9	1.4	1.2	0.83			
Jav3-a2d	6/29/2005	0.005	0.05	1.2	0.01	0.12	1.4	1.4	0.86			
Jav3-a2d	7/13/2005	0.005	0.22	2.2	0.14	0.35	0.5	1.6	1.38			
Jav3-a2d	7/27/2005	0.005	0.36	2.2			2.2	4	0.55			
Jav3-a2d	8/10/2005	0.005	0.18	2			1.1	2.5	0.80			
Jav3-a2d	8/23/2005	0.005	0.05	1.8			1.4	2.4	0.75			
Jav3-a2d	9/29/2005	0.01	0.05	1.6			1.3	2.8	0.57			
Jav3-a2d	10/27/2005	0.005	0.05	2			1.6	3.2	0.63			
Jav3-a2d	12/1/2005	0.005	0.16	2.2			1.3	2	1.10			

Jav3-a2d	1/12/2006	0.005	0.05	3.4	1.4	2.3	1.48		
Jav3-a2d	2/9/2006	0.005	0.05	4.4	3	2.7	1.63		
Jav3-a2d	3/9/2006	0.005	0.05	4.6	2.2	2.7	1.70		
Jav3-a2d	4/13/2006	0.005	0.05	4.6	1.8	2.6	1.77		
Jav3-a2d	5/12/2006	0.005	0.05	3.7	1.3	2	1.85		
Jav3-a2d	6/8/2006	0.005	0.05	4.2	1.8	2.4	1.75		
Jav3-a2d	8/10/2006	0.01	0.22	3.6	1.9	5.3	0.68		
JAV3-A2D	9/20/2006	0.02	0.05	2.4	1.5	2	1.20		
JAV3-A2D	10/18/2006	0.01	0.05	2.5	2.1	2.8	0.89		
JAV3-A2D	11/21/2006	0.005	0.05	2.2	1.5	3.2	0.69		
JAV3-A2D	12/20/2006	0.005	0.05	1.7	1.5	2.6	0.65		
JAV3-A2D	1/24/2007	0.005	0.05	0.98	1.8	3.6	0.27		
JAV3-A2D	2/21/2007	0.01	0.05	1.1	1.3	3.2	0.34		
JAV3-A2D	3/21/2007	0.005	0.05	1.3	1.7	3.7	0.35		
JAV3-A2D	Apr-07	0.005	0.05	1.6	1.7	5.9	0.27		
JAV3-A2D	May-07	0.01	0.05	1.9	1.7	5.8	0.33		
JAV3-A2D	Jun-07	0.01	0.05	2.2	1.4	5.9	0.37		
JAV3-A2D	Jul-07	0.02	0.05	2.5	1.5	7.9	0.32		
JAV3-A2D	Aug-07	0.005	0.05	3.4	1.6	9.2	0.37		
JAV3-A2D	Sep-07	0.005	0.05	4.2	1.4	10.9	0.39		
JAV3-A2D	Oct-07	0.04	0.05	4.8	3.1	10.1	0.48		
JAV3-A2D	Nov-07	0.03	0.05	4.2	2.1	9.4	0.45		
JAV3-A2D	4/22/2008	0.03	0.02	5.47	4.3	14.75	0.37		
JAV3-A2D	5/13/2008	0.03	0.04	4.33	3.77	12.74	0.34		
JAV3-A2D	6/10/2008	0.02	0.01	4.63	5.71	11.58	0.40		
JAV3A2D	8/6/2008		0.13	6.34		11.58	0.55		18.57
JAV3-A2D	9/24/2008		0.031	4.92		11.8	0.42		
JAV3-A2D	10/22/2008		0.02	5.18		1.08	4.80		
JAV3-A2D	11/19/2008		0.016	6.44		9.71	0.66		2.4
JAV3-A2D	12/17/2008		0	6.51		10.77	0.60		
JAV3-A2D	1/23/2009		0.05	5.26		32.49	0.16		
JAV3A2D	2/17/2009		0.006	4.01		8.13	0.49		1.36
JAV3A2D	3/24/2009			4.36		7.82	0.56		
JAV3A2D	4/21/2009			3.33		7.06	0.47		1.32
JAV3A2D	5/28/2009			2.25		5.42	0.42		
JAV3A2D	6/29/2009		0.04	2.93		5.79	0.51	3.9	7.9
JAV3A2D	7/21/2009			2.79		5.67	0.49		
JAV3A2D	8/18/2009			2.43		5.63	0.43	4	1
JAV3A2D	9/15/2009			2.79		5.93	0.47		
JAV3A2D	10/20/2009		0.04	3.54		6.29	0.56		4.96
JAV3A2D	11/17/2009			3.69		5.41	0.68		
JAV3A2D	12/15/2009			2.68		5.9	0.45		2.49
JAV3A2D	1/19/2010			2.02		4.9	0.41		
JAV3A2D	3/16/2010			2.15		4.88	0.44		
JAV3A2D	4/22/2010			2.33		4.31	0.54		

JAV3A2D 5/18/2010 2.42 4.53 0.53

Block 3, Transect A, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-a3s	1/12/2005	0.02	0.05	0.28	0.03	0.62						
Jav3-a3s	1/26/2005	0.02	0.05	0.31	0.01	0.97						
Jav3-a3s	2/9/2005	0.005	0.05	0.35	0.02	0.7						
Jav3-a3s	2/23/2005	0.005	0.05	0.44	0.01	0.38						
Jav3-a3s	2/23/2005	0.04	0.05	0.62	0.05	0.28						
Jav3-a3s	3/10/2005	0.005	0.05	0.37	0.03	0.37	1.6	0.5	0.74			
Jav3-a3s	3/23/2005	0.005	0.05	0.34	0.02	0.18						
Jav3-a3s	4/20/2005	0.005	0.05	0.05	0.05	0.29	3.8	5.4	0.01			
Jav3-a3s	5/5/2005	0.005	0.05	0.14	0.03	0.28	1.2	4.8	0.03			
Jav3-a3s	4/6/2005	0.005	0.05	0.33	0.04	0.46	1.1	2.7	0.12			
Jav3-a3s	5/18/2005	0.005	0.05	0.17	0.08	0.35	2.7	2.3	0.07			
Jav3-a3s	6/2/2005	0.005	0.05	0.2	0.07	0.36	1.5	2	0.10			
Jav3-a3s	6/15/2005	0.005	0.05	0.16	0.03	0.4	1.4	1.6	0.10			
Jav3-a3s	7/13/2005	0.005	0.05	0.05	0.01	0.16	1.1	1.5	0.03			
Jav3-a3s	7/27/2005	0.005	0.13	0.05			2.1	4.4	0.01			
Jav3-a3s	8/10/2005	0.005	0.05	0.05			2.2	2.6	0.02			
Jav3-a3s	8/23/2005	0.005	0.05	0.17			1.4	2.8	0.06			
Jav3-a3s	12/1/2005	0.005	0.72	0.57			1.8	1.6	0.36			
Jav3-a3s	1/12/2006	0.005	0.05	0.26			1.9	2.1	0.12			
Jav3-a3s	2/9/2006	0.005	0.05	0.28			2.1	2.2	0.13			
Jav3-a3s	3/9/2006	0.005	0.05	0.33			1.4	2	0.17			
Jav3-a3s	4/13/2006	0.005	0.77	0.36			1.9	2.7	0.13			
Jav3-a3s	5/12/2006	0.005	0.05	0.28			1.7	1.5	0.19			
Jav3-a3s	6/8/2006	0.005	0.05	0.22			1.5	4.2	0.05			
Jav3-a3s	8/10/2006	0.02	0.05	0.91			2.2	1.7	0.54			
JAV3-A3S	9/20/2006	0.005	0.05	0.15			1.6	0.5	0.30			
JAV3-A3S	10/18/2006	0.05	0.05	0.36			3.5	0.5	0.72			
JAV3-A3S	11/21/2006	0.02	0.05	0.32			2.6	1.2	0.27			
JAV3-A3S	12/20/2006	0.03	0.05	0.71			2.1	1.1	0.65			
JAV3-A3S	1/24/2007	0.02	0.05	0.74			1.7	2.2	0.34			
JAV3-A3S	2/21/2007	0.03	0.05	0.62			1.7	1.5	0.41			
JAV3-A3S	3/21/2007	0.03	0.05	0.59			5	1.6	0.37			
JAV3-A3S	4/1/2007	0.07	0.05	0.46			2.6	1.9	0.24			
JAV3-A3S	5/1/2007	0.09	0.05	0.56			2.3	1.6	0.35			
JAV3-A3S	6/1/2007	0.02	0.05	0.48			1.6	1.3	0.37			
JAV3-A3S	7/1/2007	0.3	0.05	0.37			7.9	1.6	0.23			
JAV3-A3S	4/22/2008	0.03	0.01	2.44			4.7	3.29	0.74			
JAV3-A3S	5/13/2008	0.04	0.02	0.4			4.24	4.15	0.10			

JAV3-A3S	6/10/2008	0.03	0.03	0.42			5.81	4.57	0.09			
JAV3-A3S	7/8/2008		0.027	0.58				1.66	0.35	1.14	7.3	
JAV3A3S	8/6/2008		0.06	0.83				3.86	0.22			19.5
JAV3-A3S	9/24/2008		0.049	1.09				5.17	0.21			
JAV3-A3S	12/17/2008		0	6				3.16	1.90			
JAV3-A3S	1/23/2009		0.04	4.78				14.26	0.34			
JAV3A3S	2/17/2009		0.013	3.66				3.59	1.02	1.7	9.6	1.2
JAV3A3S	3/24/2009			3.89				2.71	1.44	1.61	8.1	
JAV3A3S	4/21/2009			1.19				4.47	0.27	1.73	8.6	1.43
JAV3A3S	5/28/2009			1.19				3.73	0.32	6.9	5.8	
JAV3A3S	6/29/2009		0.18	2.5				3.88	0.64			
JAV3A3S	7/21/2009			1.71				4.21	0.41	1.9	12.3	
JAV3A3S	11/17/2009			1.79				3.67	0.49	1.6	7.4	
JAV3A3S	12/15/2009			1.06				4.79	0.22			2.29
JAV3A3S	1/19/2010			1.11				3.31	0.34	1.13	5.9	
JAV3A3S	2/18/2010		0.03	0.58				3.96	0.15	1.35	5.4	2.12
JAV3A3S	3/16/2010			0.39				3.99	0.10	1.6	3.02	
JAV3A3S	4/22/2010			0.23				5.03	0.05	1.46	3.33	
JAV3A3S	5/18/2010			0.31				3.68	0.08	1.38	0.29	

Block 3, Transect A, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-a3d	1/12/2005	0.03	0.05	0.84	0.06	0.18						
Jav3-a3d	1/26/2005	0.02	0.05	0.54	0.04	0.21						
Jav3-a3d	2/9/2005	0.03	0.05	0.7	0.04	0.19						
Jav3-a3d	2/23/2005	0.02	0.05	0.3	0.18	0.41						
Jav3-a3d	3/10/2005	0.01	0.05	0.68	0.02	0.21	1.2	1.1	0.62			
Jav3-a3d	3/23/2005	0.01	0.05	1.4	0.07	0.2						
Jav3-a3d	4/6/2005	0.01	0.05	3.3	0.05	0.3	1.1	1.5	2.20			
Jav3-a3d	4/20/2005	0.005	0.05	0.35	0.08	0.32	1.2	2.3	0.15			
Jav3-a3d	5/5/2005	0.005	0.36	0.05	0.03	0.38	2.2	5.5	0.01			
Jav3-a3d	5/18/2005	0.005	0.05	0.39	0.05	0.32	2.1	2.5	0.16			
Jav3-a3d	6/2/2005	0.005	0.05	0.35	0.05	0.5	1.7	1.8	0.19			
Jav3-a3d	6/15/2005	0.005	0.05	0.42	0.01	0.23	1.4	1.6	0.26			
Jav3-a3d	6/29/2005	0.005	0.05	0.43	0.005	0.34	1.1	1.8	0.24			
Jav3-a3d	7/13/2005	0.005	0.05	0.5	0.02	0.05	1.1	1.6	0.31			
Jav3-a3d	7/27/2005	0.005	0.05	0.5			2	4.6	0.11			
Jav3-a3d	8/10/2005	0.005	0.05	0.64			1.9	3.2	0.20			
Jav3-a3d	8/23/2005	0.005	0.13	0.85			1.2	3.4	0.25			
Jav3-a3d	9/29/2005	0.01	0.05	1.3			1.3	3.8	0.34			
Jav3-a3d	10/27/2005	0.005	0.05	1.5			1.5	4	0.38			
Jav3-a3d	12/1/2005	0.005	0.19	1.3			1.9	2.4	0.54			

Jav3-a3d	1/12/2006	0.005	0.05	1.1	1.6	2.3	0.48		
Jav3-a3d	2/9/2006	0.005	0.05	0.96	1.9	2	0.48		
Jav3-a3d	3/9/2006	0.005	0.05	0.93	1.6	2.1	0.44		
Jav3-a3d	4/13/2006	0.005	0.32	0.84	1.9	1.8	0.47		
Jav3-a3d	5/12/2006	0.005	0.05	1.2	1.1	1.8	0.67		
Jav3-a3d	6/8/2006	0.005	0.05	1.2	1.4	1.9	0.63		
Jav3-a3d	8/10/2006	0.04	0.2	1.4	1.8	2.1	0.67		
JAV3-A3D	9/20/2006	0.03	0.05	1	1.3	1.2	0.83		
JAV3-A3D	10/18/2006	0.04	0.05	1.3	2	1.1	1.18		
JAV3-A3D	11/21/2006	0.03	0.05	2.3	1.5	1.7	1.35		
JAV3-A3D	12/20/2006	0.03	0.05	2	1.5	1.4	1.43		
JAV3-A3D	1/24/2007	0.02	0.05	1.7	1.3	2.5	0.68		
JAV3-A3D	2/21/2007	0.02	0.05	1.2	1.1	1.5	0.80		
JAV3-A3D	3/21/2007	0.02	0.05	0.91	1.7	1.7	0.54		
JAV3-A3D	4/1/2007	0.02	0.05	0.72	1.2	2	0.36		
JAV3-A3D	5/1/2007	0.02	0.05	0.65	1.4	1.5	0.43		
JAV3-A3D	6/1/2007	0.03	0.05	0.7	1.4	1.9	0.37		
JAV3-A3D	7/1/2007	0.03	0.05	1	1.3	3.3	0.30		
JAV3-A3D	8/20/2007	0.02	0.05	1.2	1.2	3.9	0.31		
JAV3-A3D	9/17/2007	0.02	0.05	1.3	1.1	4.6	0.28		
JAV3-A3D	10/24/2007	0.03	0.05	1.4	2.5	5.1	0.27		
JAV3-A3D	11/24/2007	0.02	0.05	1.5	1.9	3.8	0.39		
JAV3-A3D	4/22/2008	0.04	0.01	1.57	3.91	5.13	0.31		
JAV3-A3D	5/13/2008	0.06	0.21	1.06	3.76	5.18	0.20		
JAV3A3D	8/6/2008		0.06	1.64		7.11	0.23		19.19
JAV3-A3D	9/24/2008		0.054	2.15		8.49	0.25		
JAV3-A3D	10/22/2008		0.04	2.89		0.00			
JAV3-A3D	11/19/2008		0.067	2.58		7.31	0.35	2.16	10.5
JAV3-A3D	12/17/2008		0	3.26		8.87	0.37		
JAV3-A3D	1/23/2009		0.03	2.4		31.32	0.08		
JAV3A3D	2/17/2009		0.001	2.3		7.35	0.31	2.1	9.1
JAV3A3D	3/24/2009			2.21		6.55	0.34	2.17	10.2
JAV3A3D	4/21/2009			2.01		7.78	0.26	2.52	11.2
JAV3A3D	5/28/2009			1.86		6.43	0.29	2.2	7.3
JAV3A3D	6/29/2009		0.03	3.28		7.88	0.42	4.5	11.5
JAV3A3D	7/21/2009			4.2		9.29	0.45	3.3	15.1
JAV3A3D	8/18/2009			4.6		9.74	0.47	3	0.75
JAV3A3D	9/15/2009			4.75		10.64	0.45	3.15	2.7
JAV3A3D	10/20/2009		0.02	5.31		12.2	0.44	3.4	4.53
JAV3A3D	11/17/2009			5.4		11.13	0.49	3.4	12.3
JAV3A3D	12/15/2009			6.08		13.17	0.46		2.01
JAV3A3D	1/19/2010			3.28		8.21	0.40	3.02	9.1
JAV3A3D	2/18/2010		0.03	2.37		7.53	0.31	3.06	8.2
JAV3A3D	3/16/2010			1.11		6.88	0.16	2.7	3.17
JAV3A3D	4/22/2010			0.45		4.95	0.09	1.66	2.44

Block 3, Transect B, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-b1s	1/12/2005	0.03	0.17	0.60	0.28	1						
Jav3-b1s	1/26/2005	0.14	0.18	1.00	0.54	2.4						
Jav3-b1s	2/9/2005	0.005	0.17	1.80	0.05	0.42						
Jav3-b1s	2/23/2005	0.13	0.12	1.90	0.92	3.2						
Jav3-b1s	3/10/2005	0.005	0.05	2.40	0.005	0.55	1.9	2	1.20			
Jav3-b1s	3/23/2005	0.005	0.05	2.00	0.7	1.9						
Jav3-b1s	4/6/2005	0.02	0.05	0.62	0.44	1.6	1.6	2.6	0.24			
Jav3-b1s	4/20/2005	0.005	0.05	2.40	0.12	0.85	1.3	3.7	0.65			
Jav3-b1s	5/5/2005	0.005	0.05	2.00	0.16	0.7	1.7	3.2	0.63			
Jav3-b1s	5/18/2005	0.005	0.5	2.40	0.21	2.2	2.2	5.2	0.46			
Jav3-b1s	6/2/2005	0.005	0.05	2.20	0.06	1.1	2	3.4	0.65			
Jav3-b1s	6/29/2005	0.03	2.3	1.30	0.28	2.8	1.6	3.2	0.41			
Jav3-b1s	7/13/2005	0.005	0.5	1.90	0.31	1	1.2	3.9	0.49			
Jav3-b1s	1/12/2006	0.005	0.21	5.30			1.6	3.9	1.36			
Jav3-b1s	2/9/2006	0.005	0.05	5.60			4.2	3.5	1.60			
Jav3-b1s	3/9/2006	0.005	0.23	5.50			10.7	4.4	1.25			
Jav3-b1s	4/13/2006	0.005	0.12	5.40			1.1	3.9	1.38			
Jav3-b1s	6/8/2006	0.005	0.18	3.00			1.4	8.4	0.36			
Jav3-b1s	8/10/2006	0.06	0.13	2.10			2.3	13.6	0.15			
JAV3-B1S	9/20/2006	0.13	0.26	5.90			0.5	15.9	0.37			
JAV3-B1S	10/18/2006	0.11	0.05	7.90			3	15.9	0.50			
JAV3-B1S	11/21/2006	0.02	0.05	8.70			2.4	16.3	0.53			
JAV3-B1S	12/20/2006	0.06	0.05	7.10			2	15.3	0.46			
JAV3-B1S	1/24/2007	0.01	0.05	8.40			1.9	16.3	0.52			
JAV3-B1S	2/21/2007	0.03	0.05	8.60			1.8	12.8	0.67			
JAV3-B1S	3/21/2007	0.02	0.05	9.40			2	13	0.72			
JAV3-B1S	4/1/2007	0.02	0.05	10.00			1.7	13.9	0.72			
JAV3-B1S	4/22/2008	0.04	0.04	7.98			4.37	9.84	0.81			
JAV3-B1S	5/13/2008	0.04	0.02	8.10			4.82	9.71	0.83			
JAV3-B1S	6/10/2008	0.04	0.34	7.54			9.61	11.5	0.66			
JAV3-B1S	7/8/2008		0.074	8.12				9.73	0.83			
JAV3-B1S	1/23/2009		0.09	4.06				36.29	0.11			
JAV3B1S	2/17/2009											2.43
JAV3B1S	3/24/2009			6.64				7.34	0.90	5.22	26.6	
JAV3B1S	4/21/2009			5.69				7.54	0.75	5.13	28.3	2.04
JAV3B1S	5/28/2009			5.15				6.45	0.80	6.5	21.2	
JAV3B1S	11/17/2009			10.42				8.73	1.19			
JAV3B1S	12/15/2009			9.26				7.68	1.21			4.57

JAV3B1S	1/19/2010		6.58		7.33	0.90	4.57	22.3		
JAV3B1S	2/18/2010	0.04	6.4		8.23	0.78	4.35	22.4	4.03	
JAV3B1S	3/16/2010		6.56		8.85	0.74	4.5	8.46		
JAV3B1S	4/22/2010		7.09		9.62	0.74	4.27	13.02		
JAV3B1S	5/18/2010		7.25		8.27	0.88	4.46	6.23		

Block 3, Transect B, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-b1d	1/12/2005	0.04	0.05	6.2	0.07	1						
Jav3-b1d	1/26/2005	0.005	0.05	6.1	0.04	0.77						
Jav3-b1d	2/9/2005	0.005	0.05	6.7	0.04	0.42						
Jav3-b1d	2/23/2005	0.01	0.05	6.7	0.06	0.54						
Jav3-b1d	3/10/2005	0.005	0.05	7.3	0.005	0.3	1.1	5.6	1.30			
Jav3-b1d	3/23/2005	0.005	0.05	2.1	0.05	0.16						
Jav3-b1d	4/6/2005	0.005	0.05	5.6	0.07	0.32	0.5	6.2	0.90			
Jav3-b1d	4/20/2005	0.005	0.1	6.4	0.09	0.77	1.6	8.3	0.77			
Jav3-b1d	5/5/2005	0.005	0.05	5.9	0.04	0.28	0.5	10	0.59			
Jav3-b1d	5/18/2005	0.005	0.05	6.2	0.04	0.5	1.7	8.1	0.77			
Jav3-b1d	6/2/2005	0.005	0.05	5.7	0.07	0.77	1.7	6.1	0.93			
Jav3-b1d	6/15/2005	0.005	0.05	5.7	0.03	0.33	1.2	5.6	1.02			
Jav3-b1d	6/29/2005	0.005	0.05	5.6	0.02	0.59	1.3	5.5	1.02			
Jav3-b1d	7/13/2005	0.005	0.05	5.6	0.04	0.22	0.5	5.2	1.08			
Jav3-b1d	7/27/2005	0.005	0.19	5.4			1.8	8.3	0.65			
Jav3-b1d	8/10/2005	0.005	1	5			1.8	7	0.71			
Jav3-b1d	8/23/2005	0.005	0.05	5.9			1.3	7.4	0.80			
Jav3-b1d	9/29/2005	0.005	0.05	6			1.4	7.7	0.78			
Jav3-b1d	10/27/2005	0.005	0.05	6.3			0.5	7.9	0.80			
Jav3-b1d	12/1/2005	0.005	0.14	5.9			1.7	5.3	1.11			
Jav3-b1d	1/12/2006	0.005	0.05	6.4			1.3	6.2	1.03			
Jav3-b1d	2/9/2006	0.005	0.05	6.8			1.7	6	1.13			
Jav3-b1d	3/9/2006	0.005	0.05	6.4			2.2	5.7	1.12			
Jav3-b1d	4/13/2006	0.005	0.2	6			1.2	4.6	1.30			
Jav3-b1d	5/12/2006	0.005	0.05	6.1			1.6	4.3	1.42			
Jav3-b1d	6/8/2006	0.005	0.05	6.2			1.3	8.2	0.76			
Jav3-b1d	8/10/2006	0.01	0.15	7.2			1.7	7.9	0.91			
JAV3-B1D	9/20/2006	0.11	1.8	8.3			3.9	7.9	1.05			
JAV3-B1D	10/18/2006	0.005	0.05	9.3			2.2	7.1	1.31			
JAV3-B1D	11/21/2006	0.005	0.05	9.4			1.6	7.4	1.27			
JAV3-B1D	12/20/2006	0.03	0.05	10.2			1.8	7.6	1.34			
JAV3-B1D	1/24/2007	0.005	0.05	9.4			1.1	8.7	1.08			
JAV3-B1D	2/21/2007	0.005	0.05	9.7			1.2	9.4	1.03			
JAV3-B1D	3/21/2007	0.005	0.05	9.6			2.1	9.9	0.97			

JAV3-B1D	4/1/2007	0.005	0.05	10.1		1.3	11.2	0.90				
JAV3-B1D	6/1/2007	0.005	0.05	9.5		1.5	10.8	0.88				
JAV3-B1D	7/1/2007	0.01	0.05	9.3		1.5	13	0.72				
JAV3-B1D	8/20/2007	0.005	0.21	9.4		1.9	13.5	0.70				
JAV3-B1D	9/17/2007	0.01	0.11	10.7		1.5	12.9	0.83				
JAV3-B1D	10/24/2007	0.01	0.38	10.3		4.8	13.3	0.77				
JAV3-B1D	11/24/2007	0.01	0.05	9.4		2.2	10.5	0.90				
JAV3-B1D	4/22/2008	0.04	0.01	8.96		4.98	12.22	0.73				
JAV3-B1D	5/13/2008	0.05	0.03	9.08		3.92	12.22	0.74				
JAV3-B1D	6/10/2008	0.03	0.03	9.05		5.75	13.99	0.65				
JAV3-B1D	7/8/2008		0.109	9.25			10.92	0.85				
JAV3B1D	8/6/2008		0.05	9.79			13.9	0.70				19.11
JAV3-B1D	9/24/2008		0.045	9.03			14.12	0.64				
JAV3-B1D	10/22/2008		0.03	9.26			0.58	16.02				
JAV3-B1D	11/19/2008		0.032	9.19			12.72	0.72				2.94
JAV3-B1D	12/17/2008		0	9.47			12.63	0.75				
JAV3-B1D	1/23/2009		0.07	8.2			52.08	0.16				
JAV3B1D	2/17/2009		0.004	9.07			10.71	0.85				1.14
JAV3B1D	3/24/2009			10.92			12.03	0.91	4	15.7		
JAV3B1D	4/21/2009			9.57			12.02	0.80	4.36	21.4	1.38	
JAV3B1D	5/28/2009			9.64			10.99	0.88	31.5	16.7		
JAV3B1D	6/29/2009		0.04	9.51			10.31	0.92	4.1	17.9	2.33	
JAV3B1D	7/21/2009			9.32			10.34	0.90	5.2	27.8		
JAV3B1D	8/18/2009			9.89			10.81	0.91	4.3	1.59	2.41	
JAV3B1D	9/15/2009			10.29			11.28	0.91	4.73	4.4		
JAV3B1D	11/17/2009			11.02			11.47	0.96	4.2	15.2		
JAV3B1D	12/15/2009			10.08			11.55	0.87			2.6	
JAV3B1D	1/19/2010			10.49			10.54	1.00	3.8	18		
JAV3B1D	2/18/2010		0.03	11.19			11.52	0.97	4.38	17.8	4.81	
JAV3B1D	3/16/2010			9.91			10.49	0.94				
JAV3B1D	4/22/2010			10.61			11.48	0.92	4.09	10.87		
JAV3B1D	5/18/2010			10.01			11.54	0.87	4.63	7.11		

Block 3, Transect B, Well Position 2 (Mid-Buffer), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-b2s	1/12/2005	0.02	0.25	0.79	0.08	0.9						
Jav3-b2s	1/26/2005	0.01	0.05	0.85	0.06	1.2						
Jav3-b2s	2/9/2005	0.005	0.05	1.1	0.05	0.45						
Jav3-b2s	2/23/2005	0.005	0.05	0.94	0.04	0.39						
Jav3-b2s	3/10/2005	0.005	0.05	1.1	0.02	0.28	0.5	1.6	0.69			
Jav3-b2s	3/23/2005	0.005	0.05	1.9	0.01	0.19						
Jav3-b2s	4/6/2005	0.005	0.05	5.2	0.06	0.2	1.2	2.7	1.93			

Jav3-b2s	4/20/2005	0.005	0.05	1.2	0.06	0.67	1.3	3.6	0.33			
Jav3-b2s	5/5/2005	0.005	0.05	1.1	0.05	0.38	1.1	3.9	0.28			
Jav3-b2s	5/18/2005	0.005	0.05	1.1	0.05	0.42	1.5	3.5	0.31			
Jav3-b2s	6/2/2005	0.005	0.05	0.91	0.06	0.74	2.3	2.5	0.36			
Jav3-b2s	6/15/2005	0.005	0.05	0.98	0.01	0.37	0.5	2.4	0.41			
Jav3-b2s	6/29/2005	0.005	0.05	0.96	0.02	0.26	0.5	2.4	0.40			
Jav3-b2s	7/13/2005	0.005	0.05	1	0.04	0.29	0.5	2.6	0.38			
Jav3-b2s	7/27/2005	0.005	0.05	0.98			1.4	5.6	0.18			
Jav3-b2s	8/10/2005	0.005	0.05	0.63			1.6	4.1	0.15			
Jav3-b2s	1/12/2006	0.005	0.1	1.1			1.3	5.1	0.22			
Jav3-b2s	2/9/2006	0.005	0.12	0.76			1.8	5	0.15			
Jav3-b2s	3/9/2006	0.005	0.05	0.78			2.7	4.5	0.17			
Jav3-b2s	4/13/2006	0.005	0.05	0.97			1.8	5.1	0.19			
Jav3-b2s	5/12/2006	0.005	0.05	1			1.3	3.7	0.27			
Jav3-b2s	6/8/2006	0.005	0.05	1			1.6	6.9	0.14			
Jav3-b2s	8/10/2006	0.02	0.05	1.8			1.9	3.9	0.46			
JAV3-B2S	9/20/2006	0.08	0.05	0.24			4.6	2.9	0.08			
JAV3-B2S	10/18/2006	0.02	0.05	0.05			2.9	2.9	0.02			
JAV3-B2S	11/21/2006	0.005	0.05	0.36			2.3	3.1	0.12			
JAV3-B2S	12/20/2006	0.005	0.05	0.05			2.5	2.2	0.02			
JAV3-B2S	1/24/2007	0.005	0.05	0.05			2.4	3.2	0.02			
JAV3-B2S	2/21/2007	0.005	0.05	0.05			1.8	2.2				
JAV3-B2S	3/21/2007	0.005	0.05	0.55			1.9	2.2	0.25			
JAV3-B2S	4/1/2007	0.01	0.05	0.25			1.9	2.6	0.10			
JAV3-B2S	5/1/2007	0.02	0.15	0.41			2.9	2.1	0.20			
JAV3-B2S	4/22/2008	0.02	0.01	0.42			3.63	4.36	0.10			
JAV3-B2S	5/13/2008	0.03	0.02	0.09			4.22	3.73	0.02			
JAV3-B2S	6/10/2008	0.02	0.06	0.16			4.75	4.92	0.03			
JAV3-B2S	7/8/2008		0.023	0.83				2.51	0.33			
JAV3B2S	8/6/2008		0.3	1.25				6.4	0.20			
JAV3-B2S	1/23/2009		0.09	0.68				55.46	0.01			
JAV3B2S	2/17/2009		0.038	0.21				10.56	0.02			1.92
JAV3B2S	3/24/2009			2.56				5.33	0.48			
JAV3B2S	4/21/2009			0.73				5.58	0.13			1.73
JAV3B2S	5/28/2009			0.08				7.02	0.01			
JAV3B2S	6/29/2009		0.11	0.35				6.91	0.05	3.6	6.5	3.07
JAV3B2S	11/17/2009			0.82				8.18	0.10			
JAV3B2S	12/15/2009			0.31				8.5	0.04			2.62
JAV3B2S	1/19/2010			1.38				5.62	0.25			
JAV3B2S	2/18/2010		0.07	0.45				4.09	0.11			1.54
JAV3B2S	3/16/2010			0.19				4.15	0.05		4.28	
JAV3B2S	4/22/2010			0.03				4.69	0.01			
JAV3B2S	5/18/2010			0.11				5.89	0.02			

Block 3, Transect B, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-b2d	1/12/2005	0.04	0.05	0.73	0.13	0.53						
Jav3-b2d	1/26/2005	0.01	0.05	0.77	0.11	0.36						
Jav3-b2d	2/9/2005	0.005	0.05	0.91	0.01	0.26						
Jav3-b2d	2/23/2005	0.02	0.05	0.9	0.12	0.34						
Jav3-b2d	3/10/2005	0.005	0.05	1.6	0.005	0.76						
Jav3-b2d	3/23/2005	0.005	0.05	1.6	0.05	0.24						
Jav3-b2d	4/20/2005	0.005	0.05	1.3	0.06	0.22	1.1	3.1	0.42			
Jav3-b2d	5/5/2005	0.005	0.05	1	0.04	0.32	1.4	3.7	0.27			
Jav3-b2d	4/6/2005	0.005	0.05	1.4	0.06	0.31	0.5	3.1	0.45			
Jav3-b2d	5/18/2005	0.005	0.05	1.1	0.09	0.48	1	3.2	0.34			
Jav3-b2d	6/2/2005	0.005	0.05	1.1	0.07	0.43	1.6	2.4	0.46			
Jav3-b2d	6/15/2005	0.005	0.05	1	0.005	0.35	0.5	2.2	0.45			
Jav3-b2d	6/29/2005	0.005	0.05	0.85	0.04	0.36	0.5	2.2	0.39			
Jav3-b2d	7/13/2005	0.005	0.05	1	0.04	0.13	0.5	2.1	0.48			
Jav3-b2d	7/27/2005	0.005	0.05	0.96			1.4	4.8	0.20			
Jav3-b2d	8/10/2005	0.005	0.05	0.97			1.7	3.6	0.27			
Jav3-b2d	8/23/2005	0.005	0.05	1			1.2	3.5	0.29			
Jav3-b2d	9/29/2005	0.005	0.05	0.96			1.4	3.5	0.27			
Jav3-b2d	10/27/2005	0.005	0.05	1			1.1	3.5	0.29			
Jav3-b2d	12/1/2005	0.005	0.05	1.1			1.3	2.2	0.50			
Jav3-b2d	1/12/2006	0.005	0.05	1.2			1.5	3.8	0.32			
Jav3-b2d	2/9/2006	0.005	0.05	1.1			1.6	3.4	0.32			
Jav3-b2d	3/9/2006	0.005	0.05	1			6.2	3.1	0.32			
Jav3-b2d	4/13/2006	0.005	0.05	1.1			2.1	3.7	0.30			
Jav3-b2d	5/12/2006	0.005	0.05	1.1			1.3	2	0.55			
Jav3-b2d	6/8/2006	0.005	0.05	1			1.3	4	0.25			
Jav3-b2d	8/10/2006	0.02	0.12	1.1			1.9	4.1	0.27			
JAV3-B2D	9/20/2006	0.02	0.1	0.87			1.6	1.9	0.46			
JAV3-B2D	10/18/2006	0.03	0.05	0.05			2.4	1.8	0.03			
JAV3-B2D	11/21/2006	0.01	0.05	0.4			2.1	3.1	0.13			
JAV3-B2D	12/20/2006	0.02	0.05	0.19			1.7	2.6	0.07			
JAV3-B2D	1/24/2007	0.005	0.05	0.16			1.7	3.7	0.04			
JAV3-B2D	2/21/2007	0.02	0.05	0.17			1.7	2.2	0.08			
JAV3-B2D	3/21/2007	0.005	0.05	0.7			1.3	2.4	0.29			
JAV3-B2D	4/1/2007	0.01	0.05	0.29			1.6	2.8	0.10			
JAV3-B2D	5/1/2007	0.03	0.05	0.74			1.6	2	0.37			
JAV3-B2D	6/1/2007	0.04	0.05	0.74			1.4	1.8	0.41			
JAV3-B2D	7/1/2007	0.03	0.05	0.8			1.5	2.4	0.33			
JAV3-B2D	8/20/2007	0.03	0.05	0.93			1.4	2.4	0.39			
JAV3-B2D	9/17/2007	0.02	0.05	1			1.3	3.1	0.32			
JAV3-B2D	10/24/2007	0.04	0.05	1.1			2.6	2.9	0.38			

JAV3-B2D	11/24/2007	0.06	0.05	1.6			2.9	3.4	0.47			
JAV3-B2D	4/22/2008	0.02	0.01	0.12			3.98	4.07	0.03			
JAV3-B2D	5/13/2008	0.02	0.02	0.06			4.2	4.46	0.01			
JAV3-B2D	6/10/2008	0.04	0.02	1.08			5.23	4.94	0.22			
JAV3-B2D	7/8/2008		0.034	0.58				2.67	0.22			
JAV3B2D	8/6/2008		0.2	1.75				4.63	0.38			18.44
JAV3-B2D	9/24/2008		0.055	1.77				5.06	0.35			
JAV3-B2D	10/22/2008		0.01	1.90				0.00				
JAV3-B2D	11/19/2008		0.013	2.04				4.05	0.50			1.99
JAV3-B2D	12/17/2008		0	0.56				9.42	0.06			
JAV3-B2D	1/23/2009		0.06	1.58				35.57	0.04			
JAV3B2D	2/17/2009		0.007	1.43				6.7	0.21			1.08
JAV3B2D	3/24/2009			1.2				4.79	0.25			
JAV3B2D	4/21/2009			0.13				5.9	0.02			1.38
JAV3B2D	5/28/2009			1.69				4.47	0.38			
JAV3B2D	6/29/2009		0.07	2.12				4.9	0.43	2.1	5	1.74
JAV3B2D	7/21/2009			2.31				5.19	0.45			
JAV3B2D	8/18/2009			1.91				5.31	0.36	2.6	0.54	1.62
JAV3B2D	9/15/2009			2.13				5.67	0.38			
JAV3B2D	10/20/2009		0.06	2.17				5.27	0.41			4.64
JAV3B2D	11/17/2009			0.88				16.03	0.05			
JAV3B2D	12/15/2009			0.02				9.42	0.00			2.53
JAV3B2D	1/19/2010			0.1				6.08	0.02			
JAV3B2D	2/18/2010		0.04	0.09				5.68	0.02			2.03
JAV3B2D	3/16/2010			0.09				5.81	0.02	4.4	10.24	
JAV3B2D	4/22/2010			0.01				6.48	0.00			
JAV3B2D	5/18/2010			0.24				6.32	0.04			

Block 3, Transect B, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-b3s	1/12/2005	0.02	0.11	0.11	0.12	0.19						
Jav3-b3s	1/26/2005	0.005	0.05	0.26	0.07	0.2						
Jav3-b3s	2/9/2005	0.005	0.05	0.48	0.02	0.37						
Jav3-b3s	3/10/2005	0.005	0.05	0.71	0.02	0.25	1.1	1.1	0.65			
Jav3-b3s	3/23/2005	0.005	0.05	1.2	0.05	0.05						
Jav3-b3s	4/20/2005	0.005	0.05	0.05	0.06	0.68	1.4	6.6	0.01			
Jav3-b3s	5/5/2005	0.005	0.05	0.72	0.05	0.28	1.2	15.2	0.05			
Jav3-b3s	5/5/2005	0.02	0.05	0.16	0.06	0.17	1.2	35.3	0.00			
Jav3-b3s	4/6/2005	0.005	0.05	0.86	0.06	0.51	1.4	3.6	0.24			
Jav3-b3s	5/18/2005	0.005	0.05	0.9	0.07	0.41	1.8	3.3	0.27			
Jav3-b3s	6/2/2005	0.005	0.05	0.84	0.07	0.75	1.5	2.5	0.34			
Jav3-b3s	6/15/2005	0.005	0.05	0.62	0.03	0.39	1.3	2.6	0.24			

Jav3-b3s	6/29/2005	0.005	0.05	0.33	0.01	0.2	1.3	2.4	0.14								
Jav3-b3s	7/13/2005	0.005	0.05	0.34	0.02	0.21	0.5	2.4	0.14								
Jav3-b3s	7/27/2005	0.005	0.05	0.27			1.8	5.2	0.05								
Jav3-b3s	8/10/2005	0.005	0.31	0.18			1.4	4.1	0.04								
Jav3-b3s	8/23/2005	0.005	0.05	0.25			1.6	4.3	0.06								
Jav3-b3s	12/1/2005	0.005	0.05	0.95			1.9	2.7	0.35								
Jav3-b3s	1/12/2006	0.005	0.05	0.31			1.9	1.9	0.16								
Jav3-b3s	2/9/2006	0.005	0.05	0.23			3.4	2	0.12								
Jav3-b3s	3/9/2006	0.005	0.05	0.29			2.1	2.3	0.13								
Jav3-b3s	4/13/2006	0.005	0.05	0.37			1.6	2	0.19								
Jav3-b3s	5/12/2006	0.005	0.05	0.18			1.7	1.8	0.10								
Jav3-b3s	6/8/2006	0.005	0.2	0.26			1.3	4.4	0.06								
Jav3-b3s	8/10/2006	0.03	0.12	0.36			3	1.5	0.24								
JAV3-B3S	9/20/2006	0.03	0.05	0.05			2.8	1.1	0.05								
JAV3-B3S	10/18/2006	0.02	0.05	0.05			3.4	0.5	0.10								
JAV3-B3S	11/21/2006	0.01	0.05	0.19			2.1	0.5	0.38								
JAV3-B3S	12/20/2006	0.005	0.05	0.12			1.7	0.5	0.24								
JAV3-B3S	1/24/2007	0.005	0.05	0.11			1.5	1.5	0.07								
JAV3-B3S	2/21/2007	0.01	0.05	0.12			2.4	0.5									
JAV3-B3S	3/21/2007	0.005	0.05	0.15			2	1	0.15								
JAV3-B3S	4/1/2007	0.01	0.05	0.16			1.5	1.3	0.12								
JAV3-B3S	5/1/2007	0.02	0.05	0.14			2	0.5									
JAV3-B3S	6/1/2007	0.08	1.4	< 0.1			2.4	0.5									
JAV3-B3S	4/22/2008	0.02	0.01	1.38			3.37	5.22	0.26								
JAV3-B3S	5/13/2008	0.03	0.02	1.04			4.53	4.37	0.24								
JAV3-B3S	6/10/2008	0.03	0.08	1.03			4.8	4.9	0.21								
JAV3-B3S	7/8/2008		0.017	1.24				2.42	0.51	2.45	7						
JAV3B3S	8/6/2008		0.11	1.24				5.05	0.25							18.85	
JAV3-B3S	12/17/2008		0	0.79				5.2	0.15								
JAV3-B3S	1/23/2009		0.04	0.62				38.3	0.02								
JAV3B3S	2/17/2009		0.023	0.53				5.34	0.10	3.7	7.3					0.88	
JAV3B3S	3/24/2009							3.37		5.94	5.6						
JAV3B3S	4/21/2009			0.14				3.24	0.04	4.03	6.4					1.34	
JAV3B3S	5/28/2009			0.67				3.52	0.19	3.5	4.5						
JAV3B3S	6/29/2009		0.07	0.57				3.99	0.14								
JAV3B3S	7/21/2009			1.21				4.14	0.29	4	10.9						
JAV3B3S	11/17/2009			0.06				6.71	0.01	8.3	9.2						
JAV3B3S	12/15/2009			0.05				5.27	0.01							2.41	
JAV3B3S	1/19/2010			1.44				3.63	0.40	6.34	5						
JAV3B3S	2/18/2010		0.04	0.05				2.73	0.02	3.6	5.5					2.24	
JAV3B3S	3/16/2010			0.01				3.08	0.00	4.5	9.28						
JAV3B3S	4/22/2010			0.18				4.22	0.04	3.27	2.29						
JAV3B3S	5/18/2010			0.2				4.51	0.04	4.79	0.36						

Block 3, Transect B, Well Position 3 (Stream Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-b3d	1/12/2005	0.09	0.05	0.48	0.1	0.64						
Jav3-b3d	1/26/2005	0.005	0.05	0.54	0.06	0.41						
Jav3-b3d	2/9/2005	0.03	0.05	0.72	0.03	0.31						
Jav3-b3d	2/23/2005	0.01	0.05	0.78	0.05	0.3						
Jav3-b3d	3/10/2005	0.005	0.05	0.9	0.01	0.29	1	1.1	0.82			
Jav3-b3d	3/23/2005	0.005	0.05	0.88	0.1	0.05						
Jav3-b3d	4/6/2005	0.01	0.05	0.18	0.04	0.21	0.5	1.7	0.11			
Jav3-b3d	4/20/2005	0.005	0.05	1.1	0.06	0.4	1.1	2.7	0.41			
Jav3-b3d	5/5/2005	0.005	0.05	1	0.04	0.38	1.7	37.2	0.03			
Jav3-b3d	5/18/2005	0.005	0.05	1.4	0.02	0.34	1.1	3.1	0.45			
Jav3-b3d	6/2/2005	0.005	0.05	1.4	0.06	0.63	1.1	2.4	0.58			
Jav3-b3d	6/15/2005	0.005	0.05	1.4	0.02	0.31	1.5	2.4	0.58			
Jav3-b3d	6/29/2005	0.005	0.05	1.4	0.005	0.28	1.2	2.6	0.54			
Jav3-b3d	7/13/2005	0.005	0.11	1.4	0.01	0.19	0.5	2.5	0.56			
Jav3-b3d	7/27/2005	0.005	0.16	1.2			2	5.2	0.23			
Jav3-b3d	8/10/2005	0.005	0.05	1			1.3	4.1	0.24			
Jav3-b3d	8/23/2005	0.005	0.05	0.97			1.2	4	0.24			
Jav3-b3d	9/29/2005	0.005	0.05	0.93			1.6	3.9	0.24			
Jav3-b3d	10/27/2005	0.005	0.19	1.2			1.3	4	0.30			
Jav3-b3d	12/1/2005	0.005	0.05	1.5			1.3	2.4	0.63			
Jav3-b3d	1/12/2006	0.005	0.05	1.4			1.4	2.7	0.52			
Jav3-b3d	2/9/2006	0.005	0.05	1.5			2	2.4	0.63			
Jav3-b3d	3/9/2006	0.005	0.05	1.4			1.4	3.8	0.37			
Jav3-b3d	4/13/2006	0.03	0.05	1.1			2.9	3.3	0.33			
Jav3-b3d	5/12/2006	0.005	0.05	0.96			1.3	2.1	0.46			
Jav3-b3d	6/8/2006	0.005	0.15	0.94			1.3	5.2	0.18			
Jav3-b3d	8/10/2006	0.02	0.05	0.62			2.2	1.4	0.44			
JAV3-B3D	9/20/2006	0.01	0.05	0.05			1.7	1.2	0.04			
JAV3-B3D	10/18/2006	0.005	0.05	0.19			2.2	0.5	0.38			
JAV3-B3D	11/21/2006	0.005	0.05	0.45			1.7	0.5	0.90			
JAV3-B3D	12/20/2006	0.005	0.05	0.3			1.5	0.5	0.60			
JAV3-B3D	1/24/2007	0.005	0.05	0.19			1.3	1.2	0.16			
JAV3-B3D	2/21/2007	0.005	0.05	0.2			1.6	0.5				
JAV3-B3D	3/21/2007	0.005	0.05	0.17			2.7	0.5				
JAV3-B3D	4/1/2007	0.005	0.05	0.24			1.4	1.7	0.14			
JAV3-B3D	5/1/2007	0.01	0.05	0.28			1.8	1.3	0.22			
JAV3-B3D	6/1/2007	0.005	0.05	0.17			1.4	1.7	0.10			
JAV3-B3D	7/1/2007	0.005	0.05	0.22			1.8	2.3	0.10			
JAV3-B3D	8/20/2007	0.005	0.05	0.25			1.3	2.4	0.10			
JAV3-B3D	9/17/2007	0.005	0.05	0.27			1.4	2.9	0.09			
JAV3-B3D	10/24/2007	0.005	0.05	0.38			2.7	2.4	0.16			

JAV3-B3D	11/24/2007	0.005	0.05	0.35			2.3	1.5	0.23			
JAV3-B3D	4/22/2008	0.02	0.01	0.33			3.09	3.02	0.11			
JAV3-B3D	5/13/2008	0.03	0.04	0.38			4.16	3.6	0.11			
JAV3-B3D	6/10/2008	0.02	0.04	0.81			4.74	4.44	0.18			
JAV3-B3D	7/8/2008		0.041	1.08				2.74	0.39	1.18	6.9	
JAV3B3D	8/6/2008		0.04	0.88				5.68	0.15			18.43
JAV3-B3D	9/24/2008		0.022	2.92				7.33	0.40			
JAV3-B3D	10/22/2008		0.01	3.82				0.00				
JAV3-B3D	11/19/2008		0.082	4.06				10.61	0.38	2.07	12.7	6.48
JAV3-B3D	12/17/2008		0.01	2.54				8.52	0.30			
JAV3-B3D	1/23/2009		0.05	1.5				34.91	0.04			
JAV3B3D	2/17/2009		0.01	1.28				4.68	0.27	1.6	8.7	0.58
JAV3B3D	3/24/2009			0.69				3.33	0.21	1.77	7.4	
JAV3B3D	4/21/2009			0.97				3.61	0.27	1.58	8.8	1.35
JAV3B3D	5/28/2009			1.14				3.5	0.33	57.1	5.6	
JAV3B3D	6/29/2009		0.04	2.09				3.64	0.57	1.2	5.6	2.12
JAV3B3D	7/21/2009			1.86				4.9	0.38	1.9	12.8	
JAV3B3D	8/18/2009			1.62				5.38	0.30	1.6	0.65	1.62
JAV3B3D	9/15/2009			2.34				6.21	0.38	1.58	2.2	
JAV3B3D	10/20/2009		0.02	2.71				7.25	0.37	1.5	2.77	4.89
JAV3B3D	11/17/2009			1.44				5.3	0.27	2.1	8.4	
JAV3B3D	12/15/2009			0.76				4.86	0.16			2.07
JAV3B3D	1/19/2010			1.6				3.94	0.41	1.47	7.5	
JAV3B3D	2/18/2010		0.04	1.92				4.25	0.45	1.53	8.2	2.42
JAV3B3D	3/16/2010			2.72				4.34	0.63	1.7	1.4	
JAV3B3D	4/22/2010			3.21				4.74	0.68	1.32	4.76	
JAV3B3D	5/18/2010			3.09				4.3	0.72	1.58	2.5	

Block 3, Transect C, Well Position 1 (Pasture Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	NA mg/L	Ca mg/L	DOC mg/L
Jav3-c1s	1/12/2005	0.005	0.12	0.34	0.03	0.46						
Jav3-c1s	1/26/2005	0.005	0.05	0.80	0.04	0.38						
Jav3-c1s	2/9/2005	0.005	0.05	2.00	0.02	0.49						
Jav3-c1s	2/23/2005	0.005	0.05	4.70	0.02	0.43						
Jav3-c1s	3/10/2005	0.005	0.05	4.40	0.02	0.33	2	3.3	1.33			
Jav3-c1s	3/23/2005	0.04	0.05	1.50	0.08	0.2						
Jav3-c1s	4/6/2005	0.005	0.05	0.54	0.11	0.78	1.3	3.6	0.15			
Jav3-c1s	4/20/2005	0.005	0.05	6.00	0.03	0.7	1.2	5	1.20			
Jav3-c1s	5/5/2005	0.005	0.05	5.70	0.05	0.3	1.5	44.7	0.13			
Jav3-c1s	5/18/2005	0.005	0.05	6.00	0.08	0.44	1.1	5.9	1.02			
Jav3-c1s	6/2/2005	0.005	0.05	6.00	0.07	0.47	1.2	5.8	1.03			
Jav3-c1s	6/15/2005	0.005	0.05	6.00	0.03	0.26	1.3	5.7	1.05			

Jav3-c1s	6/29/2005	0.005	0.11	4.40	0.01	0.41	2.1	5.7	0.77				
Jav3-c1s	7/13/2005	0.005	0.05	3.20	1.9	4	1.1	6.4	0.50				
Jav3-c1s	1/12/2006	0.005	0.05	5.00			1.2	79.2	0.06				
Jav3-c1s	2/9/2006	0.005	0.14	10.60			2.3	65.1	0.16				
Jav3-c1s	3/9/2006	0.005	0.05	10.20			1.5	50.1	0.20				
Jav3-c1s	4/13/2006	0.005	0.52	6.60			2	34	0.19				
Jav3-c1s	6/8/2006	0.005	0.4	5.40			1.2	45.4	0.12				
Jav3-c1s	8/10/2006	0.02	0.31	0.43			3.7	15.6	0.03				
JAV3-C1S	9/20/2006	0.04	0.18	0.85			3.2	12	0.07				
JAV3-C1S	10/18/2006	0.03	0.05	0.73			3.2	10.7	0.07				
JAV3-C1S	11/21/2006	0.005	0.05	1.30			2.2	10.8	0.12				
JAV3-C1S	12/20/2006	0.005	0.05	1.60			1.9	12.8	0.13				
JAV3-C1S	1/24/2007	0.02	0.05	3.00			2.1	15.1	0.20				
JAV3-C1S	4/1/2007	0.005	0.05	3.50			1.9	13.5	0.26				
JAV3-C1S	5/1/2007	0.09	0.27	3.50			2.8	12.2	0.29				
JAV3-C1S	4/22/2008	0.02	0.03	9.24			4.15	11.95	0.77				
JAV3-C1S	5/13/2008	0.04	0.02	7.01			4.92	10.82	0.65				
JAV3-C1S	6/10/2008	0.02	0.19	3.34			6.41	10.28	0.32				
JAV3-C1S	7/8/2008		0.089	5.98				9.5	0.63				
JAV3C1S	8/6/2008		0.19	5.43				13.11	0.41				
JAV3-C1S	12/17/2008		0	2.34				6.96	0.34				
JAV3-C1S	1/23/2009		0.04	10.84				66.1	0.16				
JAV3C1S	2/17/2009		0.022	7.71				9.98	0.77				2.86
JAV3C1S	3/24/2009			12.31				14.09	0.87	6.11	35.3		
JAV3C1S	4/21/2009			9.37				14.16	0.66	5.53	30.2		2.66
JAV3C1S	5/28/2009			8.58				13.05	0.66	5.4	21.2		
JAV3C1S	11/17/2009			9.99				4.34	2.30	6.2	22.3		
JAV3C1S	12/15/2009			5.09				6.21	0.82				3.11
JAV3C1S	1/19/2010			4.76				6.45	0.74	3.91	20.7		
JAV3C1S	2/18/2010		0.03	3.44				5.82	0.59	3.65	16.2		2.69
JAV3C1S	3/16/2010			3.76				6.34	0.59	3.8	1.67		
JAV3C1S	4/22/2010			4.17				7.55	0.55	3.75	10.21		
JAV3C1S	5/18/2010			4.25				7.23	0.59	4.16	5.65		

Block 3, Transect C, Well Position 1 (Pasture Edge), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	NA mg/L	Ca mg/L	DOC mg/L
Jav3-c1d	1/12/2005	0.02	0.05	1.1	0.06	0.35						
Jav3-c1d	1/26/2005	0.005	0.05	1.6	0.04	0.16						
Jav3-c1d	2/9/2005	0.005	0.13	2.3	0.02	0.54						
Jav3-c1d	2/23/2005	0.02	0.05	2.4	0.17	0.72						
Jav3-c1d	3/10/2005	0.005	0.05	2.9	0.02	0.3	1.7	4.2	0.69			
Jav3-c1d	3/23/2005	0.005	0.05	3.1	0.04	0.05						

Jav3-c1d	4/6/2005	0.01	0.05	3.7	0.05	0.27	1.3	4.9	0.76			
Jav3-c1d	4/20/2005	0.005	0.05	3.5	0.07	0.25	1.6	7	0.50			
Jav3-c1d	5/5/2005	0.005	0.05	3.6	0.05	0.2	1.4	20.9	0.17			
Jav3-c1d	5/18/2005	0.005	0.05	4.3	0.1	0.53	1.8	7	0.61			
Jav3-c1d	6/2/2005	0.005	0.05	4.8	0.02	0.81	1.1	5.6	0.86			
Jav3-c1d	6/15/2005	0.005	0.05	5	0.02	0.2	0.5	5.4	0.93			
Jav3-c1d	6/29/2005	0.005	0.05	5.3	0.02	0.23	1.2	5.6	0.95			
Jav3-c1d	7/13/2005	0.005	0.05	5.7	0.03	0.25	1.1	5.4	1.06			
Jav3-c1d	7/27/2005	0.005	0.22	5.4			2.2	10	0.54			
Jav3-c1d	8/10/2005	0.005	0.05	5.6			1.3	7.6	0.74			
Jav3-c1d	8/23/2005	0.005	0.05	5.5			1.3	7.5	0.73			
Jav3-c1d	9/29/2005	0.005	1.1	5.8			1.6	8.8	0.66			
Jav3-c1d	12/1/2005	0.005	0.11	4.8			1.7	5.8	0.83			
Jav3-c1d	1/12/2006	0.005	0.16	5.4			1.5	6.3	0.86			
Jav3-c1d	2/9/2006	0.005	0.05	5.7			1.9	8.4	0.68			
Jav3-c1d	3/9/2006	0.005	0.05	5.1			1.5	11.8	0.43			
Jav3-c1d	4/13/2006	0.02	0.05	4.9			1.9	23.2	0.21			
Jav3-c1d	5/12/2006	0.005	0.05	5.1			1.4	26.8	0.19			
Jav3-c1d	6/8/2006	0.005	0.05	5.2			1.3	39.4	0.13			
Jav3-c1d	8/10/2006	0.02	0.05	3.8			1.8	25.8	0.15			
JAV3-C1D	9/20/2006	0.01	0.05	3.1			1.7	19.7	0.16			
JAV3-C1D	10/18/2006	0.005	0.05	1.9			2.2	16.7	0.11			
JAV3-C1D	11/21/2006	0.005	0.05	2.7			1.6	15.6	0.17			
JAV3-C1D	12/20/2006	0.005	0.05	2.6			1.5	14	0.19			
JAV3-C1D	1/24/2007	0.005	0.05	3.7			1.4	16.5	0.22			
JAV3-C1D	4/1/2007	0.005	0.05	4.1			1.5	14.7	0.28			
JAV3-C1D	5/1/2007	0.02	0.05	3.8			2.1	11.6	0.33			
JAV3-C1D	6/1/2007	0.03	0.11	3.2			2.1	10.6	0.30			
JAV3-C1D	7/1/2007	0.03	0.05	3.2			2.5	12.3	0.26			
JAV3-C1D	11/24/2007	0.06	0.05	3.6			3	11.6	0.31			
JAV3-C1D	4/22/2008	0.03	0.01	17.17			3.6	16.63	1.03			
JAV3-C1D	5/13/2008	0.04	0.06	14.12			4.98	16.27	0.87			
JAV3-C1D	6/10/2008	0.03	0.01	9.88			5.68	16.41	0.60			
JAV3-C1D	7/8/2008		0.025	6.6				10.62	0.62			
JAV3C1D	8/6/2008		0.03	4.23				11.38	0.37		18.98	
JAV3-C1D	9/24/2008		0.039	4.75				13.36	0.36			
JAV3-C1D	12/17/2008		0	6.36				12.32	0.52			
JAV3-C1D	1/23/2009		0.04	4.86				49.18	0.10			
JAV3C1D	2/17/2009		0.007	5.73				6.99	0.82		1.69	
JAV3C1D	3/24/2009			5.69				9.1	0.63	7.55	23.4	
JAV3C1D	4/21/2009			6.53				12.35	0.53	7.37	25.4	1.77
JAV3C1D	5/28/2009			7.87				13.74	0.57	6.5	20.3	
JAV3C1D	6/29/2009		0.07	7.05				10.86	0.65	6.1	19.3	2.5
JAV3C1D	7/21/2009			6.85				11.54	0.59	7.2	30.2	
JAV3C1D	11/17/2009			6.3				9.25	0.68	8.7	18.4	

JAV3C1D	12/15/2009		6.08		7.39	0.82				3.32
JAV3C1D	1/19/2010		5.58		5.61	0.99	6.43	25.2		
JAV3C1D	2/18/2010	0.06	4.44		5.98	0.74	6.28	17.2	2.6	
JAV3C1D	3/16/2010		4.3		6.74	0.64	5.6	6.79		
JAV3C1D	4/22/2010		4.22		7.29	0.58	4.95	10.81		
JAV3C1D	5/18/2010		4.16		7.07	0.59	4.86	6.24		

Block 3, Transect C, Well Position 2 (Mid-Buffer), Shallow Depth 1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	NA mg/L	Ca mg/L	DOC mg/L
Jav3-c2s	1/12/2005	0.01	0.57	2.1	0.06	1.2						
Jav3-c2s	1/26/2005	0.005	0.05	1.8	0.08	0.44						
Jav3-c2s	2/9/2005	0.005	0.05	2	0.02	0.25						
Jav3-c2s	2/23/2005	0.005	0.05	1.9	0.005	0.37						
Jav3-c2s	3/10/2005	0.005	0.05	1.8	0.01	0.35	1.3	4.5	0.40			
Jav3-c2s	3/23/2005	0.005	0.05	2.1	0.01	0.12						
Jav3-c2s	4/20/2005	0.005	0.05	1.1	0.09	0.3	1.3	6	0.18			
Jav3-c2s	5/5/2005	0.005	0.24	1.1	0.12	1.1	1.4	14.5	0.08			
Jav3-c2s	4/6/2005	0.005	0.05	1.1	0.11	0.46	1.2	5.6	0.20			
Jav3-c2s	5/18/2005	0.005	0.05	1.3	0.12	0.65	1.9	6.1	0.21			
Jav3-c2s	6/2/2005	0.005	0.05	1.5	0.04	0.88	1.3	4.8	0.31			
Jav3-c2s	6/15/2005	0.005	0.05	1.6	0.03	0.11	1.4	4.5	0.36			
Jav3-c2s	6/29/2005	0.005	0.05	1.7	0.02	0.13	1.1	4.4	0.39			
Jav3-c2s	7/13/2005	0.005	0.05	1.7	0.02	0.22	0.5	4.4	0.39			
Jav3-c2s	7/27/2005	0.005	0.27	3.2			1.5	8.8	0.36			
Jav3-c2s	1/12/2006	0.005	0.05	0.57			6.8	4.7	0.12			
Jav3-c2s	2/9/2006	0.005	0.05	0.29			2.9	4.2	0.07			
Jav3-c2s	3/9/2006	0.005	0.05	0.21			1.7	3.9	0.05			
Jav3-c2s	4/13/2006	0.005	0.05	1.3			1.7	7	0.19			
Jav3-c2s	5/12/2006	0.005	0.05	0.45			1.7	3.9	0.12			
Jav3-c2s	6/8/2006	0.005	0.05	0.22			1.7	5.9	0.04			
Jav3-c2s	8/10/2006	0.02	0.2	0.14			2	9.4	0.01			
JAV3-C2S	9/20/2006	0.02	0.05	0.13			2.2	7	0.02			
JAV3-C2S	10/18/2006	0.005	0.05	0.05			3.2	9.5	0.01			
JAV3-C2S	11/21/2006	0.005	0.05	0.12			1.5	10	0.01			
JAV3-C2S	12/20/2006	0.005	0.05	0.05			1.9	10.3	0.00			
JAV3-C2S	1/24/2007	0.005	0.05	0.17			1.5	10.1	0.02			
JAV3-C2S	2/21/2007	0.005	0.05	0.23			1.8	7.9	0.03			
JAV3-C2S- (Dup?)	2/21/2007	0.01	0.05	4.3			2	13.4	0.32			
JAV3-C2S	3/21/2007	0.005	0.05	4.7			1.9	7.3	0.64			
JAV3-C2S- (Dup?)	3/21/2007	0.01	0.05	3.9			2.1	12.9	0.30			
JAV3-C2S	4/1/2007	0.005	0.05	0.15			1.5	11	0.01			

JAV3-C2S	5/1/2007	0.03	0.05	0.37			2.1	9.1	0.04		
JAV3-C2S	4/22/2008	0.02	0.01	0.01			3.8	28.88	0.00		
JAV3-C2S	5/13/2008	0.03	0.02	0.03			4.34	11.15	0.00		
JAV3-C2S	6/10/2008	0.02	0.04	0.01			4.81	10.83	0.00		
JAV3-C2S	7/8/2008		0.063	0.03				16.03	0.00		
JAV3-C2S	1/23/2009		0.1	2.54				91.2	0.03		
JAV3C2S	2/17/2009		0.017	0.41				19.4	0.02		1.07
JAV3C2S	3/24/2009			0.15				20.95	0.01		
JAV3C2S	4/21/2009			0				19.82	0.00		2.47
JAV3C2S	5/28/2009			0.03				19.88	0.00		
JAV3C2S	6/29/2009		0.26	0.84				16.75	0.05		
JAV3C2S	11/17/2009			5.42				14.24	0.38		
JAV3C2S	12/15/2009			0.25				23.16	0.01		3.13
JAV3C2S	1/19/2010			0				11.05	0.00		
JAV3C2S	2/18/2010		0.06	0.02				12.07	0.00		3.08
JAV3C2S	3/16/2010			0.01				9.61	0.00		
JAV3C2S	4/22/2010			0.01				11.41	0.00		
JAV3C2S	5/18/2010			0.04				12.19	0.00		

Block 3, Transect C, Well Position 2 (Mid-Buffer), Deep Depth (3.0 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	NA mg/L	Ca mg/L	DOC mg/L
Jav3-c2d	1/12/2005	0.01	0.33	6.2	0.04	1.2						
Jav3-c2d	1/26/2005	0.005	0.05	6.5	0.06	0.81						
Jav3-c2d	2/9/2005	0.005	0.05	7.1	0.03	0.43						
Jav3-c2d	2/23/2005	0.01	0.05	7.4	0.03	0.3						
Jav3-c2d	3/10/2005	0.005	0.05	8	0.02	0.26	1.1	11	0.73			
Jav3-c2d	3/23/2005	0.01	0.05	2.5	0.03	0.46						
Jav3-c2d	4/20/2005	0.005	0.05	7.1	0.1	0.75	0.5	14.3	0.50			
Jav3-c2d	5/5/2005	0.005	0.05	6.4	0.07	0.38	1.2	34	0.19			
Jav3-c2d	4/6/2005	0.005	0.05	7	0.05	0.5	1.6	13.6	0.51			
Jav3-c2d	5/18/2005	0.005	0.05	6.6	0.11	0.54	1.2	13.9	0.47			
Jav3-c2d	6/2/2005	0.005	0.05	6.4	0.07	0.98	0.5	11.5	0.56			
Jav3-c2d	6/15/2005	0.005	0.05	6.3	0.01	0.36	0.5	10.8	0.58			
Jav3-c2d	6/29/2005	0.005	0.18	6.4	0.005	0.48	0.5	11.4	0.56			
Jav3-c2d	7/13/2005	0.005	0.05	6.3	0.06	0.66	0.5	10.9	0.58			
Jav3-c2d	7/27/2005	0.005	0.05	6.4			2	14.3	0.45			
Jav3-c2d	8/10/2005	0.005	0.14	6.4			1.2	12.9	0.50			
Jav3-c2d	8/23/2005	0.005	1.8	6.3			1.4	12.7	0.50			
Jav3-c2d	9/29/2005	0.005	0.05	6.2			1	12.7	0.49			
Jav3-c2d	10/27/2005	0.005	0.05	6.1			1.1	12.9	0.47			
Jav3-c2d	12/1/2005	0.005	0.05	5.9			1.2	10.4	0.57			
Jav3-c2d	1/12/2006	0.005	0.1	5.4			2.6	10.3	0.52			

Jav3-c2d	2/9/2006	0.005	0.05	5.5	2	10.7	0.51			
Jav3-c2d	3/9/2006	0.005	0.05	5.3	1.5	9.8	0.54			
Jav3-c2d	4/13/2006	0.005	0.05	5.1	2	11.6	0.44			
Jav3-c2d	5/12/2006	0.005	0.05	5.2	1.3	9.6	0.54			
Jav3-c2d	6/8/2006	0.005	0.48	5.1	1.1	16.1	0.32			
Jav3-c2d	8/10/2006	0.02	0.05	3.9	2.1	8.5	0.46			
JAV3-C2D	9/20/2006	0.01	0.05	4.2	1.7	7	0.60			
JAV3-C2D	10/18/2006	0.005	0.05	4	2.3	6.4	0.63			
JAV3-C2D	11/21/2006	0.005	0.05	4.9	1.7	6.2	0.79			
JAV3-C2D	12/20/2006	0.005	0.05	5	1.5	6.3	0.79			
JAV3-C2D	1/24/2007	0.005	0.05	5	1.6	8.2	0.61			
JAV3-C2D	2/21/2007	0.005	0.05	4.8	1.3	6.6	0.73			
JAV3-C2D- (Dup?)	2/21/2007	0.005	0.05	4.2	1.6	12.6	0.33			
JAV3-C2D	3/21/2007	0.005	0.05	4.3	1.8	14.5	0.30			
JAV3-C2D- (Dup?)	3/21/2007	0.005	0.05	0.3	2.8	9.3	0.03			
JAV3-C2D	4/1/2007	0.005	0.05	4.8	1.4	8.1	0.59			
JAV3-C2D	5/1/2007	0.005	0.05	4.6	1.6	7.2	0.64			
JAV3-C2D	6/1/2007	0.02	0.05	4.5	1.5	7.1	0.63			
JAV3-C2D	7/1/2007	0.02	0.05	4.5	1.5	7.9	0.57			
JAV3-C2D	8/20/2007	0.01	0.05	4.5	2.2	10.1	0.45			
JAV3-C2D	9/17/2007	0.005	0.05	4.9	1.8	10.3	0.48			
JAV3-C2D	10/24/2007	0.02	0.19	4.2	4.9	9.7	0.43			
JAV3-C2D	11/24/2007	0.005	0.05	4.4	2.3	7.2	0.61			
JAV3-C2D	4/22/2008	0.05	0.01	3.4	3.71	31.16	0.11			
JAV3-C2D	5/13/2008	0.04	0.03	4.31	3.32	13.57	0.32			
JAV3-C2D	6/10/2008	0.03	0.02	4.26	4.81	15.64	0.27			
JAV3-C2D	7/8/2008		0.02	4.59		12.37	0.37			
JAV3C2D	8/6/2008		0.06	4.66		16.37	0.28			19.23
JAV3-C2D	9/24/2008		0.021	4.25		17.59	0.24			
JAV3-C2D	10/22/2008		0.04	4.29		0.99	4.33			
JAV3-C2D	11/19/2008		0.034	4.39		15.54	0.28	3.36	4.7	2.82
JAV3-C2D	12/17/2008		0	5.08		16.27	0.31			
JAV3-C2D	1/23/2009		0.06	5.59		91.2	0.06			
JAV3C2D	2/17/2009		0.011	5.51		14.6	0.38			0.7
JAV3C2D	3/24/2009			5.27		15.65	0.34			
JAV3C2D	4/21/2009			4.97		15.68	0.32			
JAV3C2D	5/28/2009			4.11		15.32	0.27			
JAV3C2D	6/29/2009		0.07	5.77		14.54	0.40	3.6	5.9	1.77
JAV3C2D	7/21/2009			6.15		14.93	0.41			
JAV3C2D	8/18/2009			6.08		14.36	0.42	4	0.85	1.8
JAV3C2D	9/15/2009			6.02		14.67	0.41			
JAV3C2D	10/20/2009		0.06	6.12		14.16	0.43			5.27
JAV3C2D	11/17/2009			6.93		13.12	0.53	3.4	4.2	
JAV3C2D	12/15/2009			3.08		17.75	0.17			3.74

JAV3C2D	1/19/2010		1.65	15.25	0.11	
JAV3C2D	2/18/2010	0.18	2.86	15.19	0.19	4.88
JAV3C2D	3/16/2010		1.18	13.92	0.08	
JAV3C2D	4/22/2010		2.82	14.22	0.20	
JAV3C2D	5/18/2010		1.4	13.66	0.10	

Block 3, Transect C, Well Position 3 (Stream Edge), Shallow Depth (1.5 m)

Sample ID	Date	PO4 mg/L	NH4 mg/L	NO3 mg/L	TP mg/L	TKN mg/L	TOC mg/L	Cl mg/L	N/CL mg/L	Na mg/L	Ca mg/L	DOC mg/L
Jav3-c3s	1/12/2005	0.06	0.11	0.05	0.73	1.6						
Jav3-c3s	1/26/2005	0.28	0.23	0.1	0.62	2.4						
Jav3-c3s	2/9/2005	0.15	0.05	2.5	0.53	0.84						
Jav3-c3s	2/23/2005	0.34	0.22	0.49	0.7	0.84						
Jav3-c3s	3/10/2005	0.54	0.25	0.63	1	1.8	3.3	5.3	0.12			
Jav3-c3s	3/23/2005	0.005	0.05	1.8	0.32	0.42						
Jav3-c3s	4/6/2005	0.005	0.05	2.2	0.22	0.7	2.8	8.2	0.27			
Jav3-c3s	4/20/2005	0.05	0.05	0.48	0.14	0.83	4.7	11.4	0.04			
Jav3-c3s	5/5/2005	0.04	0.05	0.05	0.18	0.53	5.6	30.2	0.00			
Jav3-c3s	5/18/2005	0.005	0.05	0.05	0.11	0.6	6.1	7.7	0.01			
Jav3-c3s	6/2/2005	0.005	0.05	0.24	0.14	0.85	2.2	6.2	0.04			
Jav3-c3s	6/15/2005	0.005	0.05	0.19	0.15	0.96	1.8	5.9	0.03			
Jav3-c3s	6/29/2005	0.005	0.05	0.32	0.23	0.66	2	5.8	0.06			
Jav3-c3s	7/13/2005	0.005	0.05	0.65	0.87	2.5	1.4	5.6	0.12			
Jav3-c3s	7/27/2005	0.005	0.05	0.79			2.6	10.5	0.08			
Jav3-c3s	1/12/2006	0.14	0.15	0.37			7.9	16.6	0.02			
Jav3-c3s	2/9/2006	0.02	0.05	0.64			5.4	7.8	0.08			
Jav3-c3s	3/9/2006	0.09	0.11	0.37			14.8	15.6	0.02			
Jav3-c3s	4/13/2006	0.005	0.05	1.2			2.2	6.4	0.19			
Jav3-c3s	5/12/2006	0.005	0.05	0.33			1.8	5.2	0.06			
Jav3-c3s	6/8/2006	0.005	0.05	0.15			0.5	5.3	0.03			
Jav3-c3s	8/10/2006	1.2	0.13	0.92			3.8	6.6	0.14			
JAV3-C3S	9/20/2006	1.1	0.18	0.05			2.9	5	0.01			
JAV3-C3S	10/18/2006	0.86	0.18	0.05			3.5	4.1	0.01			
JAV3-C3S	11/21/2006	0.49	0.05	0.97			0.5	4.2	0.23			
JAV3-C3S	12/20/2006	0.49	0.05	1.3			1.7	3.6	0.36			
JAV3-C3S	1/24/2007	0.47	0.05	1.9			1.2	5.1	0.37			
JAV3-C3S	2/21/2007	0.67	0.05	1.6			2.1	3.8	0.42			
JAV3-C3S	3/21/2007	0.67	0.05	1.8			3	4.1	0.44			
JAV3-C3S	4/1/2007	0.41	0.05	1.1			1.8	4.8	0.23			
JAV3-C3S	5/1/2007	0.28	0.05	0.92			2.3	4	0.23			
JAV3-C3S	4/22/2008	0.37	0.01	1.77			3.6	33	0.05			
JAV3-C3S	5/13/2008	0.92	0.01	1.27			4.79	7.65	0.17			
JAV3-C3S	6/10/2008	0.1	0.06	1.42			5.02	8.76	0.16			

Jav3-c3d	6/8/2006	0.005	0.05	2.5	1.6	9.2	0.27			
Jav3-c3d	8/10/2006	0.03	0.29	2.2	2.2	5.4	0.41			
JAV3-C3D	9/20/2006	0.03	0.05	1.6	1.7	3.2	0.50			
JAV3-C3D	10/18/2006	0.01	0.05	1.5	2.4	2.6	0.58			
JAV3-C3D	11/21/2006	0.04	0.05	1.9	1.2	2.5	0.76			
JAV3-C3D	12/20/2006	0.005	0.05	1.2	1.2	1.3	0.92			
JAV3-C3D	1/24/2007	0.005	0.05	1.9	1.3	3.8	0.50			
JAV3-C3D	2/21/2007	0.01	0.05	1.8	1.3	3.1	0.58			
JAV3-C3D	3/21/2007	0.01	0.05	1.7	2.4	3	0.57			
JAV3-C3D	4/1/2007	0.005	0.05	1.6	1.5	3.5	0.46			
JAV3-C3D	5/1/2007	0.03	0.05	1.6	1.7	2.8	0.57			
JAV3-C3D	6/1/2007	0.02	0.05	1.6	1.8	2.3	0.70			
JAV3-C3D	7/1/2007	0.02	0.05	1.8	1.5	3.1	0.58			
JAV3-C3D	8/20/2007	0.01	0.05	1.7	1.6	3	0.57			
JAV3-C3D	9/17/2007	0.01	0.05	2	1.8	3.9	0.51			
JAV3-C3D	10/24/2007	0.03	0.12	2	3.2	3.6	0.56			
JAV3-C3D	11/24/2007	0.01	0.05	2	2.4	2.6	0.77			
JAV3-C3D	4/22/2008	0.05	0.01	2.21	4.09	15.83	0.14			
JAV3-C3D	5/13/2008	0.06	0.07	1.93	3.94	5.61	0.34			
JAV3-C3D	6/10/2008	0.04	0.01	1.34	4.73	6.05	0.22			
JAV3-C3D	7/8/2008		0.08	1.3		3.87	0.34	2.33	4	
JAV3C3D	8/6/2008		0.06	1.26		6.3	0.20			17.84
JAV3-C3D	9/24/2008		0.044	1.66		6.53	0.25			
JAV3-C3D	10/22/2008		0.04	2.25		0.00				
JAV3-C3D	11/19/2008		0.012	1.52		5.19	0.29			2.11
JAV3-C3D	12/17/2008		0.01	2.01		6.08	0.33			
JAV3-C3D	1/23/2009		0.04	2.26		83.1	0.03			
JAV3C3D	2/17/2009		0.001	2.42		5.99	0.40	3.6	4.3	0.88
JAV3C3D	3/24/2009			2.35		5.86	0.40	2.89	4.4	
JAV3C3D	4/21/2009			1.59		6.49	0.24	2.91	6.1	2.66
JAV3C3D	5/28/2009			1.57		6.43	0.24	2.2	2.6	
JAV3C3D	6/29/2009		0.08	1.75		5.77	0.30	2.5	1	2.02
JAV3C3D	7/21/2009			1.92		6.48	0.30	3.3	7.7	
JAV3C3D	8/18/2009			2.1		6.56	0.32	2.4	0.35	1.49
JAV3C3D	9/15/2009			2.48		7.34	0.34	2.76	1.1	
JAV3C3D	10/20/2009		0.03	2.14		6.78	0.32	2.8	0.2	3.98
JAV3C3D	11/17/2009			1.69		6.06	0.28			
JAV3C3D	12/15/2009			1.59		7.42	0.21			2.35
JAV3C3D	1/19/2010			1.38		6.74	0.20	1.99	5.2	
JAV3C3D	2/18/2010		0.03	1.46		7.53	0.19	2.04	4.7	1.42
JAV3C3D	3/16/2010			1.57		8.15	0.19	2.2	1.67	
JAV3C3D	4/22/2010			1.52		9.07	0.17	2.05	1.86	
JAV3C3D	5/18/2010			1.86		9.27	0.20	2.31	0	